डेडीकेटेड फ्रेट कोरीडोर

DESIGN AND CONSTRUCTION OF CIVIL, STRUCTURES AND TRACK WORKS, INVOLVING FORMATION IN EMBANKMENT /CUTTING, BALLAST ON FORMATION, TRACK WORKS, BRIDGES, STRUCTURES, BUILDINGS, YARDS & INTEGRATION WITH INDIAN RAILWAY'S EXISTING RAILWAY SYSTEM AND TESTING & COMMISSIONING ON DESIGN-BUILD LUMP SUM BASIS OF KHURJA-PILKHANI SECTION (APPROXIMATELY 222 ROUTE KM OF SINGLE LINE) OF EASTERN DEDICATED FREIGHT CORRIDOR

CIVIL, STRUCTURES AND TRACK WORKS

CONTRACT PACKAGE NO: 303

ICB No.: **HQ/EN/EC/D-B/Khurja-Pilkhani Section**

PART-4 – REFERENCE DOCUMENT

GEOTECH DATA – VOLUME 3

KHURJA TO PILKHANI

From Km. 1367.0 (ALJN-GZB) to Km 187.5 (SRE-UMB)

GEO TECH DATA

(PARALLEL SECTIONS)

PART. 1/3

EMPLOYER: DEDICATED FREIGHT CORRIDOR CORPORATION OF INDIA LTD
(A GOVERNMENT OF INDIA ENTERPRISE)
MINISTRY OF RAILWAYS

COUNTRY: **INDIA**

KHURJA - PILKHANI SECTION
GEOTECH DATA

60	-	106000	106	498	505
61	-	108000	108	506	513
62	-	109000	109	514	521
63	-	110000	110	522	530
64	-	112000	112	531	539
Talheri - Pilkhani Section					
65	-	83720	155	540	547
66	-	84720	156	548	556
67	203	85067.664	156/3-4	557	559
68	-	86067.664	157/3-4	560	562
69	204	86683.46	157/9-158/0	563	565
70	-	87528.46	158/12-13	566	568
71	205	87857.348	159/0-1	569	571
72	-	88767.348	159/14-15	572	574
73	206	89709.387	160/13-14	575	577
74	-	90634.406	161/13-14	578	580
75	207	91634.406	162/13-14	581	582
76	-	92634.406	163/13-14	583	585
77	-	93634.406	164/13-14	586	588
78	-	94634.406	165/13-14	589	591
79	-	95634.406	166/13-14	592	594
80	208	96750.679	167/10-11	595	596
81	-	97750.679	168/10-11	597	599
82	-	103236.851	174/450	600	609
83	-	106095	177/02-03	610	621
84	-	109750	180/15-17	622	630
85	-	110750	181/15-17	631	639
86	-	114896	186/00-01	640	651
87	4	102200	173/400	652	668
88	210	101275	172/03-04	670	687
89	219	108719	179/31-37	688	706
90	227	113415	184/15-17	707	725
91	211	101774	172/900 - 173/000	726	734
92	214	104339	175/500-600	736	744
93	215	105043	176/200-300	745	753
94	216	107071	178/02-03	754	762
95	217	107915	178/30-32	763	771
96	218	108073	179/11-13	772	780
97	221	110842	182/00-01	781	789
98	223	111800	182/27-29	790	798
99	226	112886	183/27-29	799	812
100	227A	113548	184/19-21	813	823
101	228	114219	185/05-07	824	836
102	231	115538	186/17-19	837	847
Khurja RFO					
103	-	-1600	-	848	855
104	-	-2356	-	856	863

INTRODUCTION

1.0 Preamble

Dedicated Freight Corridor Corporation of India Ltd. proposed to perform operations pertaining to staking out alignment, detail engineering construction survey for detour at any location(s) as directed by the Engineer In Charge, preparation of Land Plan for section 4 & 6 notification under Indian Land Acquisition Act, 1894, identification & preparation of Land acquisition plan for dumping locations for ballast/ blanket material etc, Geotechnical investigation, preparation of G.A.D. for Minor & Major bridges along with preparation of schedule of quantities & Tender document for construction of Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with **Tender No. HQ/EN/Pre. (Works)/MTC** and the **responsibility for carrying out the above is** entrusted to **M/s. Monarch Surveys, Pune.**

*This report includes field and Laboratory test results for the **borehole location** in the proposed construction area like Major, Minor Bridges, Formation and RUB along with the recommendations of the foundation system for the proposed structures.*

1.1 Scope of Work

1.1.1 Field Work

- Sinking Standard Soil Investigation Bore Hole of 150mm diameter borehole for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) or as directed by the engineer-in-charge.
- Conducting Standard Penetration Test (SPT) at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.
- Collection of Split Spoon Soil Samples from the boreholes.
- Collection of disturbed soil samples from the boreholes.

- ❖ Collection of undisturbed soil samples from cohesive or semi cohesive soil samples whose SPT lies between 4 and 15.
- ❖ Collection of rock core samples and carrying out various laboratory testing as per relevant IS codes.

1.1.2. Laboratory Work

1.1.2.1 Soil Samples

(a) Visual and Engineering Classification

(b) Sieve Analysis/ Particle Size Analysis/ Grain Size Distribution Analysis

(i) Hydrometer Analysis/ Wet Sieve Analysis

(c) Atterberg Limits on the cohesive soils (LL, PL, SL) on fine-grained soils

(d) Specific Gravity

(e) Chemical Properties on sub-soil water/ soil sample to determine the presence of pH, Cl, SO_4 contents.

(f) Swelling Pressure Tests & Free Swelling Index

(g) Bulk Density and Moisture Content

(h) Unconfined Compression Tests on Clay Soils

(i) Box Shear Test in case of sand

(j) Tri-Axial Shear Tests

Unconsolidated undrained.

Consolidated Undrained Test with the Pressure

(k) Drained Consolidation Test representing e, Cc & Pc

1.1.2.2 Rock Samples

- Visual classification
- Moisture content, porosity and Density
- Specific gravity
- Unconfined compression test (both saturated and at in-situ water content)
- Point load strength index

1.2 Structure of the Report

- ❖ Contents
- ❖ Introduction
- ❖ Investigation Methodology & Test Results
- ❖ Tables & Figures
- ❖ Subsurface Stratification

- Foundation System
- Recommendations

INVESTIGATION METHODOLOGY & TEST RESULTS

2.0 Field Testing:

2.1 Preamble:

The Borehole was sunk at the investigation location for the proposed structure. The soil investigations were carried out for Major Bridges (up to 30m depth at each abutment and one representative pier or 5m in the refusal strata where SPT N value is more than 100, whichever is earlier), Minor Bridges or RUB or formation (up to12m depth subject to the distance between adjacent bore hole not exceeding 1000m) as directed by the engineer-in-charge.

2.2 In-Situ Strength Tests:

2.2.1 Standard Penetration Test:

Standard penetration tests (SPT) were conducted at every 3.0m interval starting from first sample at 1.5m depth or at the change of stratum as per IS: 2131-1981 or as directed by the engineer-in-charge.

2.3 Collection of Samples:

2.3.1 Soil:

2.3.1.1 Disturbed Samples

The disturbed soil samples were collected as directed by the engineer-in-charge at every change in the sub-soil strata. These samples were used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.2 Standard Penetration Tests & Split Spoon Samples

The standard penetration tests were conducted at an interval of 1.50m up to 10.0m depth below the existing ground level or at every change in the sub-soil strata as per IS: 2131-1981 or as directed by the engineer-in-charge. Split spoon samples collected were further used for visual and physical identification and for conducting laboratory classification tests as per I.S.1498-1970.

2.3.1.3 Undisturbed Soil Samples

At the borehole locations, the undisturbed soil samples were collected and presented in Fig. 2.1.

2.4 Laboratory Testing:

Soil Samples

2.4.1 Visual and Engineering Classification, Sieve Analysis Tests/ Grain Size Analysis Tests

On the soil samples visual and engineering, grain size distribution tests were conducted as per I.S.2720 (Part 4)-1985, to know the gradation characteristics and to classify them. These results are presented in Table 2.1.

2.4.2 Atterberg Limits

Atterberg Limits were carried out on fine-grained soil samples to evaluate the limits of different consistency states. Generally Liquid limits, Plastic limits and Shrinkage Limits tests were conducted as per I.S.2720 (Part-V)-1985 and I.S.2720 (Part 6)-1972. These results are presented in Table 2.1.

2.4.3 Specific Gravity

On the soil samples, specific gravity tests were conducted as per I.S: 2720 (Part-III, Sec.1)-1986. The test results are presented in Table 2.1.

2.4.4 Chemical Tests on Water Sample

These tests are being conducted on water sample as per I.S: 456-1978 and the test results are presented in table 2.2.

2.4.5 Swelling Pressure & Free Swell Tests

Generally, these tests are conducted over the fines passing through 0.075mm sieve. Since, the soil samples obtained are heterogeneous, the soil samples are sieved and the percentage of fines passing was used to determine the free swell percentage of soil. These tests are conducted as per I.S: 2720 (Part-4)-1985 and the test results are presented in table 2.1.

2.4.6 Bulk Density & Natural Moisture Content

On the soil samples, Bulk Density and natural moisture content tests were conducted as per I.S: 2720 (Part-II)-1973. The bulk density of the soil sample was determined through water displacement method and the test results are presented in Table 2.1.

2.4.7 Unconfined Compression Tests

These tests are normally conducted on clayey soils, which can stand without confinement. The tests are conducted on such soil samples and the test results are presented in table 2.1.

2.4.8 Box Shear Tests

The tests are being conducted on the remoulded compacted soil samples and were conducted under undrained conditions. The test results are presented in table 2.1.

2.4.9 Triaxial Shear Tests

These tests are normally conducted on the soil samples to determine their shear strength characteristics. The test results are presented in table 2.1.

2.4.10 Consolidation Tests

These tests are conducted to determine the compressibility characteristics of the soil. The tests are conducted in a consolidation cell with minimum diameter to thickness ratio as 3. The thickness of soil sample is taken as 20mm to get uniform distribution of pressure on the soil sample. The tests are conducted on the undisturbed soil samples and the test results are presented in Table 2.1.

Rock Samples

As no rock strata were encountered at the investigation locations, no tests on rock samples could be conducted.

KHURJA – HAFIZPUR SECTION

BRIDGE NO. 3 AT IR KM 3.116 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 24/04/2008; Ended On : 25/04/2008 G.W.T: 11.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
			Brownish Loose Sandy Clayey Silt	1.50	3	4	8	12		Loose	SS
				3.00	UDS Collected					Loose	SS
				4.50	3	4	7	11		Loose	SS
				6.00	4	6	9	15		Loose	SS
				7.50	4	8	7	15		Loose	SS
				9.00	4	5	9	14		Loose	SS
10.50				10.50	5	6	11	17		M.Dense	SS
G.W.T 12.00			Greyish Medium Dense Silty Clayey Fine Sand	12.00	8	9	16	25		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.03 Location

BRIDGE NO. 3 AT IR KM 3.116 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No.03 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-10.50	13	SS	Sandy Clayey Silt	13	-	-	-	-	2.67	0.3	15	-	-	Loose	0	0	0	25	60	15	-	-	18.9	30.3	-	-	SM
10.50-12.00	17	SS	Silty Sand	8	-	-	-	-	2.66	0.2	18	-	-	M.Dense	0	0	0	89	11	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.03

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.89	88.34	79.56

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 10.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	10.50m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance	30.90^{o}

* **Layer-2 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	17
Relative Density	Medium Dense
Angle of Shearing Resistance	32.10^{o}

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	13	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 3 AT IR KM 3.116 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 3 AT IR KM 3.116 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	11	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 19.29

N_γ = 23.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 340.59 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 136.24 kPa

Limited to an allowable bearing pressure per running meter width: 130.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 130kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 130kPa and SPT of 11 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 4 AT IR KM 3.813 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 25/04/2008; Ended On : 25/04/2008 G.W.T: 10.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
			Brownish Loose Sandy Clayey Silt	1.50	2	3	4	7	Loose	SS
				3.00	4	4	5	9	Loose	SS
				4.50	UDS Collected				Loose	SS
				6.00	4	6	9	15	Loose	SS
7.50				7.50	5	11	12	23	M.Dense	SS
			Greyish Medium Dense Silty Clayey Fine Sand	9.00	6	11	12	23	M.Dense	SS
G.W.T				10.50	7	12	15	27	M.Dense	SS
12.00				12.00	8	13	16	29	M.Dense	SS

Graphical Representation of SPT: 0 10 20 30 40 50 60 70 80 90

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.04 Location

BRIDGE NO. 4 AT IR KM 3.813 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No.04 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay: LL (%)	Clay: PL (%)	Clay: PI	Clay: Consistency, I_C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis: Gravel (%)	Sieve Analysis: Coarse (%)	Sieve Analysis: Medium (%)	Sieve Analysis: Fine (%)	Sieve Analysis: Silt (%)	Sieve Analysis: Clay (%)	Triaxial Test: c (kN/m^2)	Triaxial Test: ϕ (Deg.)	Box Shear: c (kN/m^2)	Box Shear: ϕ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-7.50	10	SS	Sandy Clayey Silt	13	-	-	-	-	2.67	0.3	15	-	-	Loose	0	0	0	23	60	17	-	-	18.6	29.6	-	-	SM
7.50-12.00	24	SS	Silty Sand	6	-	-	-	-	2.66	0.2	18	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.04

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.88	94.67	77.86

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	10
Relative Density	Loose
Angle of Shearing Resistance	30.10^o

* **Layer-2 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance	34.20^o

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the third week of May 2008.

BRIDGE NO. 4 AT IR KM 3.813

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	10	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 4 AT IR KM 3.813 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 4 AT IR KM 3.813 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	7	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	29.40	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 17.47

N_γ = 21.02

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	305.94	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	122.38	kPa
Limited to an allowable bearing pressure per running meter width:	100.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 100kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 100kPa and SPT of 07 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 5 AT IR KM 3.938 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 25/04/2008; Ended On : 27/04/2008 G.W.T: 11.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
			Brownish Medium Dense Sandy Clayey Silt	1.50	6	10	11	21		M.Dense	SS
2.50				3.00	UDS Collected					Loose	SS
			Brownish Loose Sandy Clayey Silt	4.50	6	7	8	15		Loose	SS
6.00				6.00	5	7	9	16		M.Dense	SS
			Greyish Medium Dense Silty Clayey Fine Sand	7.50	6	8	8	16		M.Dense	SS
				9.00	7	7	10	17		M.Dense	SS
	G.W.T			10.50	8	9	12	21		M.Dense	SS
12.00				12.00	9	10	16	26		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.05 Location

BRIDGE NO. 5 AT IR KM 3.938 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No.05 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-2.50	21	SS	Sandy Clayey Silt	9	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	27	61	12	-	-	16.7	32.7	-	-	SM
2.50-6.00	15	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	0.3	15	-	-	Loose	0	0	0	21	65	14	-	-	-	-	-	-	SM
6.00-12.00	18	SS	Silty Clayey Sand	8	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.05

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.78	180.43	135.24

BRIDGE NO. 5 AT IR KM 3.938 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 2.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	2.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance	33.30^{o}

* **Layer-2 (from 2.50m to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	15
Relative Density	Loose
Angle of Shearing Resistance	31.50^{o}

* **Layer-3 (from 6.00m to 12.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish
Thickness of Layer	6.00m
SPT of the layer	18
Relative Density	Medium Dense
Angle of Shearing Resistance	32.40^{o}

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the fourth week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	25	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 5 AT IR KM 3.938 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 5 AT IR KM 3.938 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	21	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 28.23

N_γ = 39.32

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u =	680.95	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	272.38	kPa
Limited to an allowable bearing pressure per running meter width:	250.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 21 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 6 AT IR KM 4.366 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 28/04/2008; Ended On : 29/04/2008 G.W.T: 11.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	SPT - Details 0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
0.50			Filled Up Soil								
			Brownish Loose Sandy Clayey Silt	1.50	4	4	5	9		M.Dense	SS
				3.00	UDS Collected					Loose	SS
				4.50	4	5	5	10		Loose	SS
				6.00	4	6	5	11		Loose	SS
				7.50	5	7	7	14		Loose	SS
8.50			Greyish Medium Dense Silty Clayey Fine Sand	9.00	7	11	12	23		M.Dense	SS
				10.50	6	9	10	19		M.Dense	SS
G.W.T 12.00				12.00	7	11	12	23		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.06 Location

BRIDGE NO. 6 AT IR KM 4.366 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No.06 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay: LL (%)	Clay: PL (%)	Clay: PI	Clay: Consistency, I_C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis: Gravel (%)	Sieve Analysis: Coarse (%)	Sieve Analysis: Medium (%)	Sieve Analysis: Fine (%)	Sieve Analysis: Silt (%)	Sieve Analysis: Clay (%)	Triaxial Test: c (kN/m^2)	Triaxial Test: ϕ (Deg.)	Box Shear: c (kN/m^2)	Box Shear: ϕ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-0.50	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.50-7.50	10	SS	Sandy Clayey Silt	12	-	-	-	-	2.67	0.3	15	-	-	Loose	0	0	0	20	64	16	-	-	19.6	29.7	-	-	SM
7.50-12.00	24	SS	Silty Clayey Sand	8	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.06

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.91	77.86	80.98

BRIDGE NO. 6 AT IR KM 4.366 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 0.50m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	0.50m

* **Layer-2 (from 0.50m to 8.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	8.00m
SPT of the layer	11
Relative Density	Loose
Angle of Shearing Resistance	30.30^{o}

* **Layer-3 (from 8.50m to 12.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish
Thickness of Layer	3.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance	33.30^{o}

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the final week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	12	47

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 6 AT IR KM 4.366 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 6 AT IR KM 4.366 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	9	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	29.80	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 18.09

N_γ = 21.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 317.45 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 126.98 kPa

Limited to an allowable bearing pressure per running meter width: 120.00 kPa

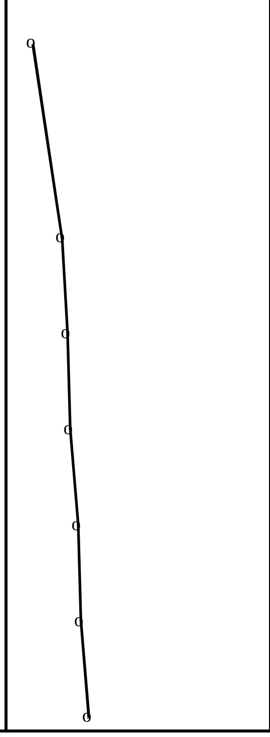
2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 09 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 7 AT IR KM 5.513 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 30/04/2008; Ended On : 01/05/2008 G.W.T: 9.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 20 30 40 50 60 70 80 90		
0.30			Filled Up Soil								
			Brownish Loose Sandy Clayey Silt	1.50	4	4	5	9		Loose	SS
				3.00	UDS Collected					Loose	SS
4.50				4.50	4	9	11	20		M.Dense	SS
			Greyish Medium Dense Silty Clayey Fine Sand	6.00	5	10	12	22		M.Dense	SS
				7.50	6	10	13	23		M.Dense	SS
				9.00	6	10	16	26		M.Dense	SS
G.W.T				10.50	8	11	16	27		M.Dense	SS
12.00				12.00	9	12	18	30		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.07 Location

BRIDGE NO. 7 AT IR KM 5.513 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No.07 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-0.30	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.30-4.50	9	SS	Sandy Clayey Silt	13	-	-	-	-	2.68	0.3	15	-	-	Loose	0	0	0	23	59	18	-	-	17.6	28.7	-	-	SM
4.50-12.00	24	SS	Silty Clayey Sand	7	-	-	-	-	2.66	0.2	17	-	-	M.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.07

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.88	100.94	112.12

BRIDGE NO. 7 AT IR KM 5.513 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 0.30m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	0.30m

* **Layer-2 (from 0.30m to 4.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	4.20m
SPT of the layer	09
Relative Density	Loose
Angle of Shearing Resistance	29.80^o

* **Layer-3 (from 4.50m to 12.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish
Thickness of Layer	7.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance	34.20^o

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the final week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	12	47

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 7 AT IR KM 5.513 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 7 AT IR KM 5.513 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	9	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	29.80	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 18.09

N_γ = 21.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	317.45	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	126.98	kPa
Limited to an allowable bearing pressure per running meter width:	120.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 09 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

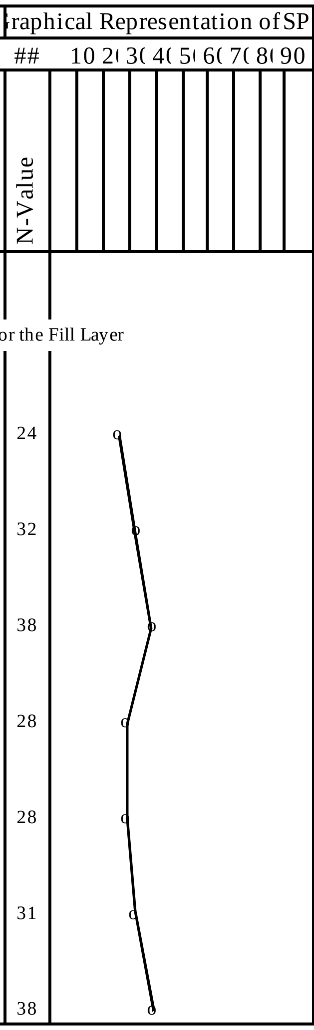
BRIDGE NO. 11 AT IR KM 6.950 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 08/05/2008; Ended On : 08/05/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
2.00			Filled Up Soil	1.50	SPT Neglected for the Fill Layer				-	DS
			Brownish Medium Dense Sandy Clayey Silt	3.00	6	9	15	24	M.Dense	SS
4.50				4.50	7	13	19	32	Dense	SS
			Greyish Dense Silty Fine Sand	6.00	10	16	22	38	Dense	SS
7.50				7.50	8	11	17	28	M.Dense	SS
9.50			Greyish Medium Dense Silty Fine Sand	9.00	6	12	16	28	M.Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	5	11	20	31	V.Dense	SS
12.00				12.00	8	13	25	38	V.Dense	SS

Graphical Representation of SPT



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.11 Location

BRIDGE NO. 11 AT IR KM 6.950 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 11 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-2.00	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.00-4.50	24	SS	Sandy Clayey Silt	9	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	21	54	25	-	-	16.7	33.2	-	-	SM
4.50-7.50	35	SS	Silty Sand	7	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM
7.50-9.00	28	SS	Silty Sand	9	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	83	17	0	-	-	-	-	-	-	SM
9.00-12.00	31	SS	Silty Sand	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 11

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm
BH-01	9.00	7.84	55.67	80.65

BRIDGE NO. 11 AT IR KM 6.950 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 2.00m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	2.00m
SPT of the layer	-

* **Layer-2 (from 2.00m to 4.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	2.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20 Deg.

* **Layer-3 (from 4.50m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	35
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.375 Deg.

* **Layer-4 (from 7.50m to 9.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.00m
SPT of the layer	28

Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.40 Deg.

* **Layer-5 (from 9.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m
SPT of the layer	31
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.275 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	1.50	24	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 11 AT IR KM 6.950 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 11 AT IR KM 6.950 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	3.50	m
Observed Maximum thickness of Filled up Soil:	2.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	24	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	34.20	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 30.92

N_γ = 43.93

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 608.70 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 243.48 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 24 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 02/05/2008; Ended On : 02/05/2008 G.W.T: 4.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
0.50			Filled Up Soil								
			Brownish Medium Dense Sandy Silt	1.50	6	8	9	17		M.Dense	SS
				3.00	6	7	14	21		M.Dense	SS
4.50				4.50	5	12	21	33		Dense	SS
			Brownish Dense Sandy Clayey Silt	6.00	9	18	23	41		Dense	SS
7.50				7.50	7	8	14	22		M.Dense	SS
			Brownish to Greyish Medium Dense Sandy Clayey Silt	9.00	9	10	16	26		M.Dense	SS
				10.50	8	11	15	26		M.Dense	SS
12.00				12.00	10	16	18	34		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.12 Location

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 12 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)			
E.G.L-0.50	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.50-4.50	19	SS	Sandy Silt	11	-	-	-	-	2.68	-	16	-	-	M.Dense	0	0	0	44	56	0	-	-	14.5	31.5	-	-	SM
4.50-7.50	37	SS	Sandy Clayey Silt	14	27	16	11	1.2	2.65	-	18	-	-	Dense	0	0	0	15	60	25	-	-	22.4	36.9	-	-	SM
7.50-12.00	25	SS	Sandy Clayey Silt	14	31	14	17	1.0	2.66	-	17	-	-	M.Dense	0	0	0	11	66	23	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 12

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.81	59.50	89.3

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 0.50m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	0.50m
SPT of the layer	-

*** Layer-2 (from 0.50m to 4.50m depth below)**

Type of Strata	Sandy Silt
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70 Deg.

*** Layer-3 (from 4.50m to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	37
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.925 Deg.

*** Layer-4 (from 7.50m to 12.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish to Greyish
Thickness of Layer	4.50m
SPT of the layer	25

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION)

Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.50 Deg.

The ground water table was encountered at a depth of 4.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	20	40

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 12 AT IR KM 7.072 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	17	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.10	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 24.66

N_γ = 33.16

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 517.32 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 206.93 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

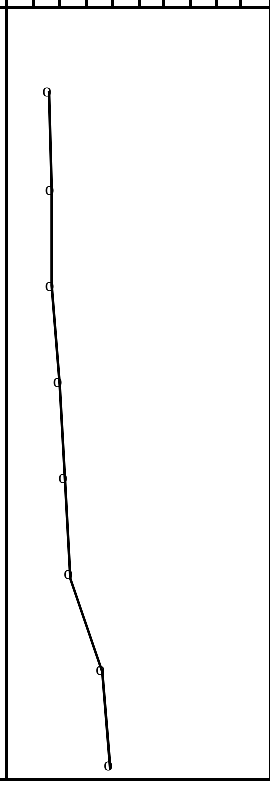
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 17 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 22 AT IR KM 11.588 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 01/05/2008; Ended On : 02/05/2008 G.W.T: 11.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
0.25			Filled Up Soil								
			Brownish Medium Dense Sandy Clayey Silt	1.50	4	8	8	16		M.Dense	SS
				3.00	4	8	9	17		M.Dense	SS
				4.50	5	8	9	17		M.Dense	SS
				6.00	5	8	11	19		M.Dense	SS
				7.50	6	9	12	21		M.Dense	SS
				9.00	8	10	13	23		M.Dense	SS
10.50				10.50	9	12	24	36		Dense	SS
G.W.T 12.00			Greyish Dense Silty Clayey Fine Sand	12.00	10	14	25	39		Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.22 Location

BRIDGE NO. 22 AT IR KM 11.588 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 22 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-0.25	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0.25-10.50	19	SS	Sandy Clayey Silt	10	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	25	51	24	-	-	18.7	31.6	-	-	SM
10.50-12.00	36	SS	Silty Sand	7	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 22

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.79	119.77	157.46

BRIDGE NO. 22 AT IR KM 11.588 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 0.25m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	0.25m
SPT of the layer	-

* **Layer-2 (from 0.25m to 10.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	10.25m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	36
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.65 Deg.

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.75m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.75m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	1.75	18	36

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 22 AT IR KM 11.588 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 22 AT IR KM 11.588 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.25	m
Effective Depth of Foundation below E.G.L:	1.75	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	16	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	31.80	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 23.76

N_γ = 31.63

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	450.89	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	180.35	kPa
Limited to an allowable bearing pressure per running meter width:	180.00	kPa

2 Settlements

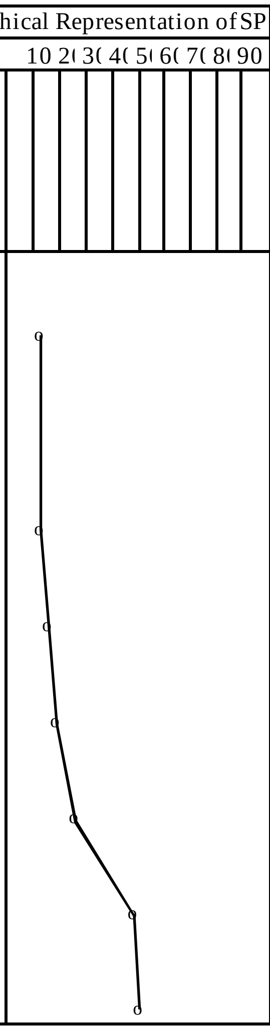
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 180kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 180kPa and SPT of 16 are computed to be in the order of 36mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 23 AT IR KM 12.292 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 02/05/2008; Ended On : 03/05/2008 G.W.T: 11.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		
			Brownish Loose Sandy Clayey Silt	1.50	4	6	7	13	Loose	SS
				3.00	UDS Collected				Loose	SS
				4.50	4	6	7	13	Loose	SS
6.00				6.00	5	7	9	16	M.Dense	SS
			Brownish Medium Dense Silty Clayey Fine Sand	7.50	6	8	11	19	M.Dense	SS
				9.00	7	10	16	26	M.Dense	SS
10.50				10.50	10	21	26	47	Dense	SS
G.W.T 12.00			Greyish Dense Silty Clayey Fine Sand	12.00	10	22	27	49	Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.23 Location

BRIDGE NO. 23 AT IR KM 12.292 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 23 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	13	DS	Sandy Clayey Silt	14	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	22	56	22	-	-	17.8	30.1	-	-	SM
6.00-10.50	20	SS	Silty Clayey Sand	10	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	85	9	6	-	-	-	-	-	-	SM
10.50-12.00	47	SS	Silty Clayey Sand	6	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	78	14	8	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 23

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.8	116.50	145.4

BRIDGE NO. 23 AT IR KM 12.292 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 6.00m to 10.50m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	20
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.00 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	47
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	40.325 Deg.

The ground water table was encountered at a depth of 11.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	15	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 23 AT IR KM 12.292 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 23 AT IR KM 12.292 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	13	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.90	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 21.08

N_γ = 27.01

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 375.37 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 29 AT IR KM 13.416 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 04/05/2008; Ended On : 05/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
			Brownish Loose Sandy Clayey Silt	1.50	4	6	9	15		Loose	SS
				3.00	UDS Collected					Loose	SS
4.50				4.50	4	7	11	18		M.Dense	SS
			Brownish Medium Dense Silty Clayey Fine Sand	6.00	5	7	12	19		M.Dense	SS
				7.50	4	8	12	20		M.Dense	SS
				9.00	5	9	14	23		M.Dense	SS
10.50				10.50	6	15	18	33		Dense	SS
12.00			Greyish Dense Silty Clayey Fine Sand	12.00	7	15	19	34		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.29 Location

BRIDGE NO. 29 AT IR KM 13.416 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 29 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	15	DS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	26	54	20	-	-	19.7	30.9	-	-	SM
4.50-10.50	20	SS	Silty Clayey Sand	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	78	15	7	-	-	-	-	-	-	SM
10.50-12.00	33	SS	Silty Clayey Sand	8	-	-	-	-	2.65	-	18	-	-	Dense	0	0	0	76	16	8	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 29

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.78	155.46	124.68

BRIDGE NO. 29 AT IR KM 13.416 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	15
Relative Density	Loose
Angle of Shearing Resistance, ϕ	31.50 Deg.

* **Layer-2 (from 4.50m to 10.50m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	20
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.00 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	33
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	36.825 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	16	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 29 AT IR KM 13.416 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 29 AT IR KM 13.416 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	15	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	31.50	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 22.87

N_γ = 30.09

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 410.14 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 164.06 kPa

Limited to an allowable bearing pressure per running meter width: 160.00 kPa

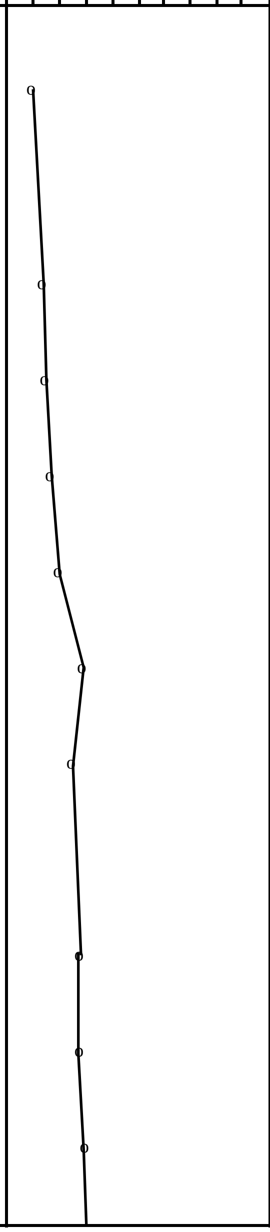
2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 15 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 32 AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 05/05/2008; Ended On : 07/05/2008 G.W.T: 10.50m

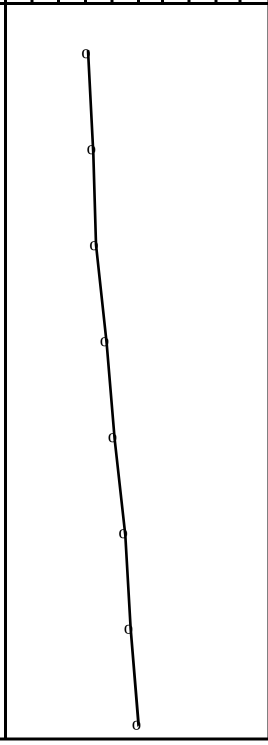
Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
			Brownish Loose Sandy Clayey Silt	1.50	4	5	5	10		Loose	SS
				3.00	UDS Collected					Loose	SS
				4.50	4	5	9	14		Loose	SS
				6.00	4	5	10	15		Loose	SS
7.50				7.50	6	7	10	17		M.Dense	SS
			Brownish Medium Dense Silty Clayey Fine Sand	9.00	6	8	12	20		M.Dense	SS
G.W.T				10.50	8	12	17	29		M.Dense	SS
				12.00	8	12	13	25		M.Dense	SS
				13.50	DS Collected					M.Dense	DS
				15.00	9	13	15	28		M.Dense	SS
				16.50	9	14	14	28		M.Dense	SS
				18.00	10	14	16	30		M.Dense	SS

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At Bridge No. 32

Started On : 05/05/2008; Ended On : 07/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Greyish Dense Silty Fine Sand	19.50	9	15	16	31		Dense	SS
				21.00	16	16	17	33		Dense	SS
				22.50	10	17	17	34		Dense	SS
				24.00	11	19	19	38		Dense	SS
				25.50	12	20	21	41		Dense	SS
				27.00	12	22	23	45		Dense	SS
				28.50	13	22	25	47		Dense	SS
30.00				30.00	14	24	26	50		Dense	SS



Bore Hole Terminated at a depth of 30.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.32 Location

BRIDGE NO. 32 AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 32 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-7.50	13	SS	Sandy Clayey Silt	13	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	21	57	22	14.8	30.1	-	-	-	-	SM
7.50-30.00	32	SS	Silty Clayey Sand	9	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	79	15	6	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 32

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.88	75.43	80.44

BRIDGE NO. 32 AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 7.50m to 30.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	22.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.55 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

BRIDGE NO. 32 AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

S.No.	Diameter of Pile (mm)	Safe Load Carrying Capacity (kN)	Safe Pull Out carrying Capacity (kN)	Safe Lateral Load carrying Capacity (kN)
1	1000	10000	5922	600

The details of the computations are annexed to this report.

BRIDGE NO. 32 AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
3. The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 32 AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)
DESIGN OF PILE FOUNDATION(Refer:BH-01)
Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**1000.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**30.000**	m
R.L. of Bot. of Pile	-30.00	m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1 **Layer-I**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	13	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	30.9	Deg.
Depth of top of Strata:	0.00	m
Depth of bottom of Strata:	7.50	m
Average Thickness of Strata,I_c:	7.50	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	37.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	18.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.00	
Skin Resistance of the pile,q_s:	264.40	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.2 **Layer-II**

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	32	
Bulk Density of the strata,γ:	19	kN/m^3
Angle of Shearing Resistance,ϕ:	36.55	Deg.
Depth of top of Strata:	7.50	m
Depth of bottom of Strata:	30.00	m
Average Thickness of Strata,I_c:	22.50	m
Effective overburden pressure over the top of strata,σ_{top}:	37.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	240.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	138.75	kN/m^2
Coeff. Of Earth Pressure,k:	2.00	
Skin Resistance of the pile,q_s:	14541.1	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		
Ultimate Skin Resistance,q_s:	**14805.5**	**kN**

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Silty Sand	
Cross-Sectional Area of pile,Ap:	0.785	m^2

	R.L of bottom of pile:	-30.00	
	Minimum SPT-value of the Bearing Strata	50	
	Angle of Shearing Resistance(ASR)	41.00	Degrees
	Bearing Capacity Factor(Nq)	150.00	
	Effecitve Over Burden Pressure at the bottom of pile (q)	100.00	kPa
	(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the N.G.L.)		
	Ultimate End Bearing Resistance (Qp)	**11781.0**	**kN**
	(Qp=Ap*q*Nq)		
1.3.0	**Ultimate Load Carrying Capacity ($Qu=Qp+q_p$)**	**26586.5**	**kN**
	Safe Load Carrying Capacity (Qsafe =Qu/2.5)	**10634.6**	**kN**
	However, limit Q_{safe} to the structural capacity of pile:	**10000.0**	**kN**

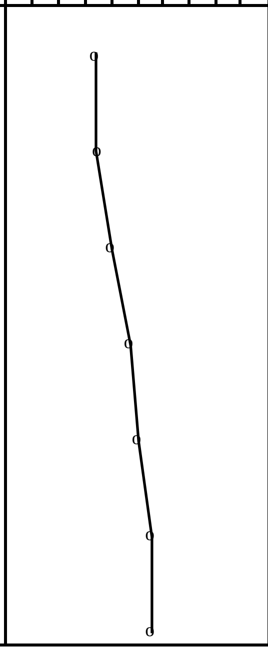
BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 08/06/2008; Ended On : 10/06/2008 G.W.T: 5.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Loose Sandy Clayey Silt	1.50	5	5	7	12		Loose	SS
				3.00	UDS Collected					Loose	SS
				4.50	4	5	5	10		Loose	SS
G.W.T				6.00	4	5	7	12		Loose	SS
				7.50	6	6	9	15		Loose	SS
9.00				9.00	6	7	9	16		M.Dense	SS
			Brownish Medium Dense Silty Fine to Medium Coarse Sand	11.00	7	13	14	27		M.Dense	SS
				12.50	7	9	12	21		M.Dense	SS
				14.00	7	8	11	19		M.Dense	DS
				15.50	Disturbed Sample Collected					M.Dense	SS
				17.00	8	11	12	23		M.Dense	SS
				18.50	9	12	14	26		M.Dense	SS
19.00											

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.
Location: At Bridge No. 32-A
Started On : 08/06/2008; Ended On : 10/06/2008 G.W.T: 5.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
				20.00	10	14	20	34		Dense	SS
				22.00	10	14	21	35		Dense	SS
			Greyish Dense Silty Fine Sand	23.50	12	16	24	40		Dense	SS
				25.00	12	18	29	47		Dense	SS
				26.50	14	19	31	50		Dense	SS
28.00				28.00	15	21	34	55		V.Dense	SS
30.00			Greyish Dense Silty Fine Sand	29.50	15	27	28	55		V.Dense	SS

Bore Hole Terminated at a depth of 30.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.32-A Location

BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 32A Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	12	SS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	18	60	22	14.3	29.8	-	-	-	-	SM
9.00-19.00	22	SS	Silty Sand	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	17	66	17	0	-	-	-	-	-	-	SM
19.00-28.00	41	SS	Silty Sand	9	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
28.00-30.00	55	SS	Silty Sand	8	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 32A

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.89	70.48	78.41

BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.60 Deg.

* **Layer-2 (from 9.00m to 19.00m depth below)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	10.00m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60 Deg.

* **Layer-3 (from 19.00m to 28.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	9.00m
SPT of the layer	41
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.975 Deg.

* **Layer-4 (from 28.00m to 30.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish

Thickness of Layer	2.00m
SPT of the layer	55
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	41.75 Deg.

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral

BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

	Pile (mm)	**Carrying Capacity (kN)**	**carrying Capacity (kN)**	**Load carrying Capacity (kN)**
1	1000	10000	4611	600

The details of the computations are annexed to this report.

BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

3. The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.

5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 32A AT IR KM 14.508 (KHURJA - HAFIZPUR SECTION)
DESIGN OF PILE FOUNDATION(Refer:BH-01)
Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile — **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**1000.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**30.000**	m
R.L. of Bot. of Pile	-30.00	m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1 **Layer-I**

Type of Strata:	Sandy Clayey Silt	
Average SPT of the strata,N:	12	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	30.6	Deg.
Depth of top of Strata:	0.00	m
Depth of bottom of Strata:	7.50	m
Average Thickness of Strata,I_c:	7.50	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	37.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	18.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.00	
Skin Resistance of the pile,q_s:	261.27	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.2 **Layer-II**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	22	
Bulk Density of the strata,γ:	17	kN/m^3
Angle of Shearing Resistance,ϕ:	33.6	Deg.
Depth of top of Strata:	9.00	m
Depth of bottom of Strata:	19.00	m
Average Thickness of Strata,I_c:	10.00	m
Effective overburden pressure over the top of strata,σ_{top}:	37.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	107.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	72.50	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q_s:	2269.9	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.3 **Layer-III**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	41	
Bulk Density of the strata,γ:	19	kN/m^3
Angle of Shearing Resistance,ϕ:	38.975	Deg.

Depth of top of Strata:	19.00	m
Depth of bottom of Strata:	28.00	m
Average Thickness of Strata,I_c:	9.00	m
Effective overburden pressure over the top of strata,σ_{top}:	107.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	188.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	148.00	kN/m^2
Coeff. Of Earth Pressure,k:	2.00	
Skin Resistance of the pile,q_s:	6771.2	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.4 Layer-IV

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	55	
Bulk Density of the strata,γ:	20	kN/m^3
Angle of Shearing Resistance,ϕ:	41.75	Deg.
Depth of top of Strata:	28.00	m
Depth of bottom of Strata:	30.00	m
Average Thickness of Strata,I_c:	2.00	m
Effective overburden pressure over the top of strata,σ_{top}:	188.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	208.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	198.50	kN/m^2
Coeff. Of Earth Pressure,k:	2.00	
Skin Resistance of the pile,q_s:	2226.4	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		
Ultimate Skin Resistance,q_s:	**11528.7**	**kN**

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Silty Sand	
Cross-Sectional Area of pile,Ap:	0.785	m^2
R.L of bottom of pile:	-30.00	
Minimum SPT-value of the Bearing Strata	55	
Angle of Shearing Resistance(ASR)	41.75	Degrees
Bearing Capacity Factor(Nq)	195.00	
Effecitve Over Burden Pressure at the bottom of pile (q)	100.00	kPa
(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the N.G.L.)		
Ultimate End Bearing Resistance (Qp)	**15315.3**	**kN**
(Qp=Ap*q*Nq)		

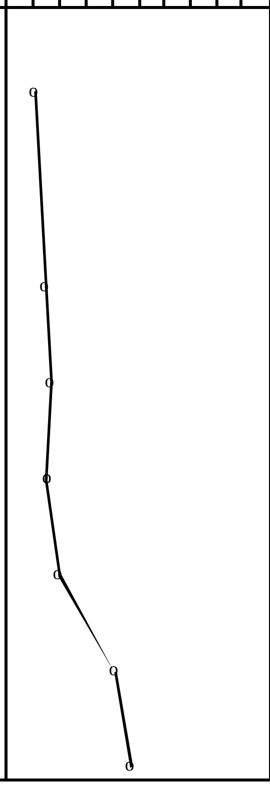
1.3.0	**Ultimate Load Carrying Capacity (Qu=Qp+q_p)**	**26844.0**	**kN**
	Safe Load Carrying Capacity (Qsafe =Qu/2.5)	**10737.6**	**kN**
	However, limit Q_{safe} to the structural capacity of pile:	**10000.0**	**kN**

BRIDGE NO. 35 AT IR KM 15.305 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 08/05/2008; Ended On : 09/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
			Brownish Loose Sandy Clayey Silt	1.50	3	4	7	11		Loose	SS
				3.00	UDS Collected					Loose	SS
				4.50	4	7	8	15		Loose	SS
6.00				6.00	4	8	9	17		M.Dense	SS
			Brownish Medium Dense Silty Clayey Fine Sand	7.50	5	8	8	16		M.Dense	SS
				9.00	7	9	11	20		M.Dense	SS
10.50				10.50	11	17	23	40		Dense	SS
12.00			Greyish Dense Silty Clayey Fine Sand	12.00	11	19	27	46		Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.35 Location

BRIDGE NO. 35 AT IR KM 15.305 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 35 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	13	DS	Sandy Clayey Silt	15	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	21	65	14	-	-	17.8	30.0	-	-	SM
6.00-10.50	18	SS	Silty Clayey Sand	9	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	81	11	8	-	-	-	-	-	-	SM
10.50-12.00	40	SS	Silty Clayey Sand	7	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	75	14	11	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 35

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.81	140.03	121.2

BRIDGE NO. 35 AT IR KM 15.305 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 6.00m to 10.50m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	18
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.40 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	40
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	38.75 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	12	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 35 AT IR KM 15.305 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 35 AT IR KM 15.305 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	11	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 19.29

N_γ = 23.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 340.59 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 136.24 kPa

Limited to an allowable bearing pressure per running meter width: 120.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 11 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 36 AT IR KM 16.237 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 09/05/2008; Ended On : 10/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Loose Sandy Clayey Silt	1.50	3	5	5	10		Loose	SS
				3.00	UDS Collected					Loose	SS
				4.50	4	5	7	12		Loose	SS
				6.00	5	7	7	14		Loose	SS
				7.50	5	7	8	15		Loose	SS
9.00				9.00	6	9	9	18		M.Dense	SS
G.W.T			Greyish to Brownish Medium Dense Silty Fine Sand	10.50	7	9	11	20		M.Dense	SS
12.00				12.00	7	10	12	22		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No. 36 Location

BRIDGE NO. 36 AT IR KM 16.237 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 36 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	13	DS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	23	68	9	-	-	16.8	30.0	-	-	SM
9.00-12.00	19	SS	Silty Sand	11	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 36

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.84	140.95	133.23

BRIDGE NO. 36 AT IR KM 16.237 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are loose deposits of coarse-grained type in the form of non-plastic sandy silt but can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	11	49

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 36 AT IR KM 16.237 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are loose deposits of coarse-grained type in the form of sandy silt but can be considered as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 36 AT IR KM 16.237 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	10	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.00	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 18.40

N_γ = 22.40

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	323.20	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	129.28	kPa
Limited to an allowable bearing pressure per running meter width:	110.00	kPa

2 Settlements

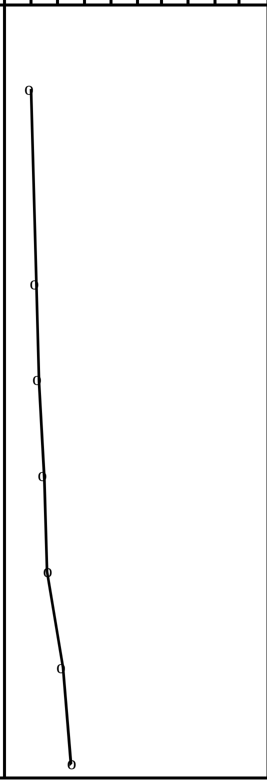
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 110kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 110kPa and SPT of 10 are computed to be in the order of 49mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 39 AT IR KM 17.170 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 11/05/2008; Ended On : 12/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Loose Sandy Clayey Silt	1.50	3	4	6	10		Loose	SS
				3.00	UDS Collected					Loose	SS
				4.50	4	5	7	12		Loose	SS
				6.00	4	5	8	13		Loose	SS
				7.50	5	7	8	15		Loose	SS
9.00				9.00	6	7	10	17		M.Dense	SS
G.W.T			Greyish to Brownish Medium Dense Silty Fine Sand	10.50	8	10	12	22		M.Dense	SS
12.00				12.00	10	13	13	26		M.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No. 39 Location

BRIDGE NO. 39 AT IR KM 17.170 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 39 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	13	DS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	26	67	7	-	-	18.7	30.0	-	-	SM
9.00-12.00	19	SS	Silty Sand	11	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 39

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.83	135.56	120.18

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	19
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.70 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	15	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 39 AT IR KM 17.170 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 39 AT IR KM 17.170 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	13	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.90	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 21.08

N_γ = 27.01

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

$Q_u =$ 375.37 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	150.15	kPa
Limited to an allowable bearing pressure per running meter width:	150.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 85 AT IR KM 33.710 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

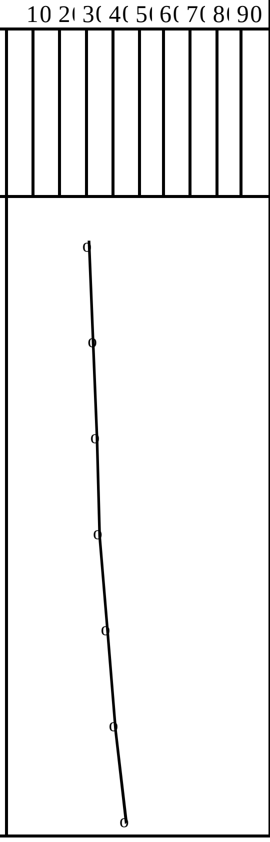
Started On : 13/05/2008; Ended On : 15/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
1.50			Filled Up Soil	1.50	3	4	6	10	Loose	SS
			Brownish Loose Sandy Clayey Silt	3.00	3	6	8	14	Loose	SS
				4.50	UDS Collected				Loose	SS
6.00				6.00	5	7	11	18	M.Dense	SS
			Brownish Medium Dense Silty Clayey Fine Sand	7.50	5	7	12	19	M.Dense	SS
				9.00	5	9	13	22	M.Dense	SS
G.W.T				10.50	6	9	13	22	M.Dense	SS
				12.00	7	10	13	23	M.Dense	SS
				13.50	8	12	14	26	M.Dense	DS
				15.00	8	12	15	27	M.Dense	SS
				17.00	9	11	16	27	M.Dense	SS
				18.50	10	12	16	28	M.Dense	SS

SPT - Details; Graphical Representation of SPT: ## 10 20 30 40 50 60 70 80 90

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.
Location: At Bridge No. 85
Started On : 13/05/2008; Ended On : 15/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SP	Relative Density/Consistency	Type of Sample
				20.00	11	13	17	30		M.Dense	SS
21.50				21.50	11	14	18	32		Dense	SS
			Greyish Dense Silty Fine Sand	23.00	11	14	19	33		Dense	SS
				24.50	10	14	20	34		Dense	SS
				26.00	10	15	22	37		Dense	SS
				27.50	12	17	23	40		Dense	SS
30.00				29.50	14	20	24	44		Dense	SS



Bore Hole Terminated at a depth of 30.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.85 Location

BRIDGE NO. 85 AT IR KM 33.710 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 85 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-1.50	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.50-6.00	12	SS	Sandy Clayey Silt	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	17	61	22	14.1	29.9	-	-	-	-	SM
6.00-21.50	27	SS	Silty Clayey Fine Sand	11	-	-	-	-	2.66	-	18	-	-	M.Dense	0	0	0	78	14	8	-	-	-	-	-	-	SM
21.50-30.00	35	SS	Silty Sand	8	-	-	-	-	2.65	-	19	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 85

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.83	111.49	89.44

BRIDGE NO. 85 AT IR KM 33.710 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 1.50m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	1.50m
SPT of the layer	-
Relative Density	-
Angle of Shearing Resistance, ϕ	-

* **Layer-2 (from 1.50m to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.60 Deg.

* **Layer-3 (from 6.00m to 21.50m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	15.50m
SPT of the layer	27
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.10 Deg.

* **Layer-4 (from 21.50m to 30.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	8.50m

SPT of the layer	35
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.375 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

S.No.	Diameter of	Safe Load	Safe Pull Out	Safe Lateral

BRIDGE NO. 85 AT IR KM 33.710 (KHURJA - HAFIZPUR SECTION)

	Pile (mm)	**Carrying Capacity (kN)**	**carrying Capacity (kN)**	**Load carrying Capacity (kN)**
1	1000	11000	4142	550

The details of the computations are annexed to this report.

BRIDGE NO. 85 AT IR KM 33.710 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
3. The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 85 AT IR KM 33.710 (KHURJA - HAFIZPUR SECTION)
DESIGN OF PILE FOUNDATION(Refer:BH-01)
Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile — **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**1000.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**30.000**	m
R.L. of Bot. of Pile	-30.00	m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1 Layer-I

Type of Strata:	Filled Up Soil	
Average SPT of the strata,N:	-	
Bulk Density of the strata,γ:	12	kN/m^3
Angle of Shearing Resistance,ϕ:	-	Deg.
Depth of top of Strata:	0.00	m
Depth of bottom of Strata:	1.50	m
Average Thickness of Strata,I_c:	1.50	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	3.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	1.50	kN/m^2
Coeff. Of Earth Pressure,k:	1.00	
Skin Resistance of the pile,q_s:	Neglected for the fill	

1.2.1.2 Layer-II

Type of Strata:	Sandy Clayey Silt	
Average SPT of the strata,N:	12	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	30.6	Deg.
Depth of top of Strata:	1.50	m
Depth of bottom of Strata:	6.00	m
Average Thickness of Strata,I_c:	4.50	m
Effective overburden pressure over the top of strata,σ_{top}:	3.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	25.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	14.25	kN/m^2
Coeff. Of Earth Pressure,k:	1.00	
Skin Resistance of the pile,q_s:	119.1	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.3 Layer-III

Type of Strata:	Silty Clayey Fine Sand	
Average SPT of the strata,N:	27	
Bulk Density of the strata,γ:	18	kN/m^3
Angle of Shearing Resistance,ϕ:	35.1	Deg.
Depth of top of Strata:	6.00	m
Depth of bottom of Strata:	21.50	m
Average Thickness of Strata,I_c:	15.50	m
Effective overburden pressure over the top of strata,σ_{top}:	25.50	kN/m^2

Effective overburden pressure over the bottom of strata, σ_{bottom}:	149.50	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	87.50	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile, q_s:	4491.8	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.4 **Layer-IV**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	35	
Bulk Density of the strata, γ:	19	kN/m^3
Angle of Shearing Resistance, ϕ:	37.375	Deg.
Depth of top of Strata:	21.50	m
Depth of bottom of Strata:	30.00	m
Average Thickness of Strata, I_c:	8.50	m
Effective overburden pressure over the top of strata, σ_{top}:	149.50	kN/m^2
Effective overburden pressure over the bottom of strata, σ_{bottom}:	226.00	kN/m^2
Effective overburden pressure at the middle of the strata, σ_{middle}:	187.75	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile, q_s:	5744.6	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		
Ultimate Skin Resistance, q_s:	**10355.5**	**kN**

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Silty Sand	
Cross-Sectional Area of pile,Ap:	0.785	m^2
R.L of bottom of pile:	-30.00	
Minimum SPT-value of the Bearing Strata	44	
Angle of Shearing Resistance(ASR)	39.65	Degrees
Bearing Capacity Factor(Nq)	220.00	
Effecitve Over Burden Pressure at the bottom of pile (q)	110.00	kPa
(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the N.G.L.)		
Ultimate End Bearing Resistance (Qp)	**19006.6**	**kN**
(Qp=Ap*q*Nq)		

1.3.0

Ultimate Load Carrying Capacity (Qu=Qp+q_p)	**29362.1**	**kN**
Safe Load Carrying Capacity (Qsafe =Qu/2.5)	**11744.9**	**kN**
However, limit Q_{safe} to the structural capacity of pile:	**11000.0**	**kN**

BRIDGE NO. 86 AT IR KM 34.403 (KHURJA - HAFIZPUR SECTION)

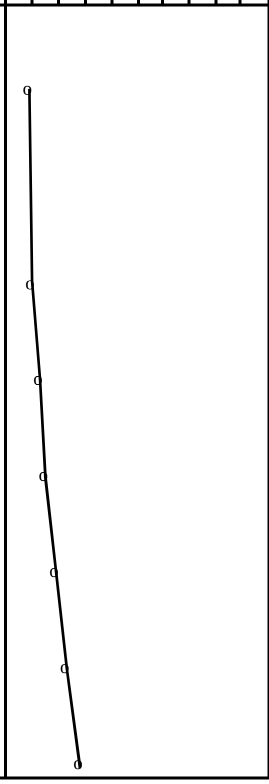
Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 11/05/2008; Ended On : 12/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
			Brownish Loose Sandy Clayey Silt	1.50	3	4	4	8	Loose	SS
				3.00	UDS Collected				Loose	SS
				4.50	3	4	5	9	Loose	SS
				6.00	4	6	7	13	Loose	SS
				7.50	5	6	9	15	Loose	SS
9.00				9.00	7	9	10	19	M.Dense	SS
G.W.T			Greyish Medium Dense Silty Fine Sand	10.50	9	11	12	23	M.Dense	SS
12.00				12.00	10	14	14	28	M.Dense	SS

Graphical Representation of SPT

10 2(3(4(5(6(7(8(90



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No. 86 Location

BRIDGE NO. 86 AT IR KM 34.403 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 86 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	11	SS	Sandy Clayey Silt	13	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	20	70	10	-	-	15.6	29.6	-	-	SM
9.00-12.00	21	SS	Silty Sand	10	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 86

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.87	133.23	121.7

BRIDGE NO. 86 AT IR KM 34.403 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	11
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.30 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.30 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt but can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	10	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 86 AT IR KM 34.403 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are loose deposits of coarse-grained type in the form of sandy clayey silt but can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 86 AT IR KM 34.403 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	8	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	29.60	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 17.78

N_γ = 21.48

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 311.69 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 124.68 kPa

Limited to an allowable bearing pressure per running meter width: 100.00 kPa

2 Settlements

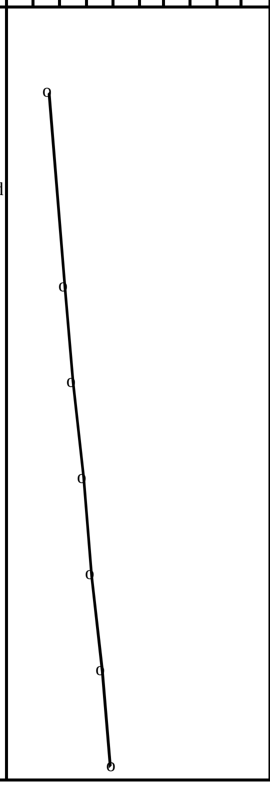
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 100kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 100kPa and SPT of 08 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

BRIDGE NO. 112 AT IR KM 46.118 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 28/05/2008; Ended On : 29/05/2008 G.W.T: 9.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
			Brownish Medium Dense Sandy Clayey Silt	1.50	7	7	9	16		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	7	10	12	22		M.Dense	SS
				6.00	9	10	15	25		M.Dense	SS
				7.50	10	13	16	29		Dense	SS
9.00				9.00	13	15	17	32		Dense	SS
			Greyish to Brownish Dense Silty Fine Sand	10.50	13	17	19	36		V.Dense	SS
12.00				12.00	14	20	20	40		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No. 112 Location

BRIDGE NO. 112 AT IR KM 46.118 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from Bridge No. 112 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	23	SS	Sandy Clayey Silt	9	-	-	-	-	2.7	-	17	-	-	Loose	0	0	0	24	56	20	-	-	21.1	32.8	-	-	SM
9.00-12.00	34	SS	Silty Sand	7	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No. 112

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.89	120.86	100.47

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	23
Relative Density	Loose
Angle of Shearing Resistance, ϕ	33.90 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	34
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.10 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the final week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	19	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

BRIDGE NO. 112 AT IR KM 46.118 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

BRIDGE NO. 112 AT IR KM 46.118 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	16	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	31.80	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 23.76

N_γ = 31.63

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	497.23	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	198.89	kPa
Limited to an allowable bearing pressure per running meter width:	190.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 16 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 08 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 05/05/2008; Ended On : 05/05/2008 G.W.T: 12.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Medium Dense Sandy Silt	1.50	8	10	11	21		M.Dense	SS
				3.00	4	10	12	22		M.Dense	SS
4.00											
			Greyish Very Stiff Silty Clay	4.50	8	10	13	23		V.Stiff	SS
				6.00	UDS Collected					V.Stiff	**UDS**
7.50				7.50	6	12	13	25		M.Dense	SS
			Brownish Medium Dense Sandy Silt	9.00	5	8	12	20		M.Dense	SS
				10.50	9	11	13	24		M.Dense	SS
12.00				12.00	12	14	13	27		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-08 Location

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IR KM 08 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-08 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.00	21	SS	Sandy Silt	11	-	-	-	-	2.7	-	16	-	-	M.Dense	0	0	0	45	55	0	13.2	32.2	-	-	-	-	SM
4.00-7.50	23	**SS, UDS**	Silty Clay	29	70	31	39	1.1	2.67	0.8	18	40	33	V.Stiff	0	0	0	0	28	72	-	-	148.1	14.4	153.3	0.54	CH
7.50-12.00	24	SS	Sandy Silt	9	-	-	-	-	2.7	-	16	-	-	M.Dense	0	0	0	47	50	3	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-08

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.81	29.80	81.09

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 4.00m depth below)**

Type of Strata	Sandy Silt
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.30 Deg.

* **Layer-2 (from 4.00m to 7.50m depth below)**

Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	3.50m
SPT of the layer	23
Consistency	Very Stiff
Undrained Cohesion, Cu	153.33kPa

* **Layer-3 (from 7.50m to 12.00m depth below)**

Type of Strata	Sandy Silt
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20 Deg.

The ground water table was encountered at a depth of 12.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/ Raft	1.50	22	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 08 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 08 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	21	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 28.23

N_γ = 39.32

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 552.49 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 220.99 kPa

Limited to an allowable bearing pressure per running meter width: 220.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 21 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 09 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 05/05/2008; Ended On : 06/05/2008 G.W.T: 12.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Medium Dense Sandy Silt	1.50	9	13	14	27		M.Dense	SS
				3.00	8	12	10	22		M.Dense	SS
				4.50	7	10	13	23		M.Dense	SS
				6.00	6	9	14	23		M.Dense	SS
				7.50	7	8	11	19		M.Dense	SS
8.50											
			Greyish Very Stiff Silty Clay	9.00	10	13	16	29		V.Stiff	SS
				10.50	UDS Collected					V.Stiff	**UDS**
12.00				12.00	10	14	19	33		Hard	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-09 Location

IR KM 09 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-09 Location																												
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-8.50	23	SS	Sandy Silt	10	-	-	-	-	2.7	-	16	-	-	M.Dense	0	0	0	41	59	0	14.5	32.6	-	-	-	-	SM
8.50-12.00	29	SS, UDS	Silty Clay	26	68	33	35	1.2	2.66	0.7	18	32	30	V.Stiff	0	0	0	0	31	69	-	-	190.5	13.9	193.3	0.52	CH

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-09				
Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.84	23.30	77.93

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 8.50m depth below)**

Type of Strata	Sandy Silt
Colour	Brownish
Thickness of Layer	8.50m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.90 Deg.

*** Layer-2 (from 8.50m to 12.00m depth below)**

Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	3.50m
SPT of the layer	29
Consistency	Very Stiff
Undrained Cohesion, Cu	193.33kPa

The ground water table was encountered at a depth of 12.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	26	46

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 09 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 09 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	27	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	35.10	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 33.92

N_γ = 49.26

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 672.33 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 268.93 kPa

Limited to an allowable bearing pressure per running meter width: 260.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 260kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 260kPa and SPT of 27 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 10 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 05/05/2008; Ended On : 06/05/2008 G.W.T: 11.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
			Brownish Very Stiff Silty Clay	1.50	7	10	13	23		V.Stiff	SS
				3.00	UDS Collected					V.Stiff	UDS
				4.50	8	10	16	26		V.Stiff	SS
6.00				6.00	6	9	12	21		M.Dense	SS
			Brownish to Greyish Medium Dense Sandy Clayey Silt	7.50	5	10	9	19		M.Dense	SS
				9.00	9	10	14	24		M.Dense	SS
10.50				10.50	11	14	17	31		M.Dense	SS
12.00			Brownish Dense Sandy Silt	12.00	10	13	20	33		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.3 Soil Profile at KM-10 Location

IR KM 10 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-10 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	24	UDS	Silty Clay	27	77	35	42	1.2	2.65	0.72	19	40	70	V.Stiff	0	0	0	0	22	78	156.5	11.3	-	-	193.3	0.6	CH
6.00-10.50	21	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	25	65	10	-	-	51.2	32.7	-	-	SM
10.50-12.00	32	SS	Sandy Silt	8	-	-	-	-	2.65	-	18	-	-	M.Dense	0	0	0	48	52	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-10

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.81	71.80	80.9

IR KM 10 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	23
Consistency	Very Stiff
Undrained Cohesion, Cu	153.33kPa

* **Layer-2 (from 6.00m to 10.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish to Greyish
Thickness of Layer	4.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.90 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Sandy Silt
Colour	Brownish to Greyish
Thickness of Layer	1.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.55 Deg.

The ground water table was encountered at a depth of 11.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic fine-grained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.50	23	46

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

The details of the computations are annexed to this report.

IR KM 10 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
4. **The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.**
5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 10 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	23	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	153.33	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	19.00	kN/m^3
Effective Overburden pressure at foundation level (q)	22.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

$N_c =$ 5.14

$N_q =$ N/A

$N_\gamma =$ N/A

Shape Factors:

$S_c =$ 1.30

$S_q =$ N/A

$S_\gamma =$ N/A

Depth Factors :

$D_c =$ 1.00

$D_q =$ N/A

$D_\gamma =$ N/A

Inclination Factor:

$I_c =$ 1.00

$I_q =$ N/A

$I_\gamma =$ N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 1024.57 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 409.83 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 260kPa and SPT of 23 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 18 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 08/05/2008; Ended On : 08/05/2008 G.W.T: 8.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
			Greyish to Brownish Very Stiff Silty Clay	1.50	7	10	12	22		V.Stiff	SS
				3.00	UDS Collected					V.Stiff	UDS
				4.50	5	9	11	20		V.Stiff	SS
				6.00	6	9	10	19		V.Stiff	SS
				7.50	6	8	13	21		V.Stiff	SS
8.50										G.W.T	
			Brownish Medium Dense Silty Fine Sand	9.00	4	9	14	23		M.Dense	SS
10.50				10.50	8	14	17	31		Dense	SS
12.00			Brownish Dense Silty Fine Sand	12.00	7	15	18	33		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-18 Location

IR KM 18 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-18 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-8.50	21	SS	Silty Clay	27	77	33	44	1.1	2.65	0.7	19	33	70	V.Stiff	0	0	0	0	24	76	138.9	12.4	-	-	140.0	0.60	CH
8.50-10.50	23	SS	Silty Sand	8	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	77	23	0	-	-	11.2	32.7	-	-	SM
10.50-12.00	31	SS	Silty Sand	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-18

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.84	44.30	74.1

IR KM 18 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 8.50m depth below)**

Type of Strata	Silty Clay
Colour	Greyish to Brownish
Thickness of Layer	8.50m
SPT of the layer	21
Consistency	Hard
Undrained Cohesion, Cu	140.00kPa

* **Layer-2 (from 8.50m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.90 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	31
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.275 Deg.

The ground water table was encountered at a depth of 8.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic fine-grained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.50	24	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 18 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
4. **The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.**
5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 18 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	22	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	146.67	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	19.00	kN/m^3
Effective Overburden pressure at foundation level (q)	22.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 980.03 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 392.01 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 22 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 19/4 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At KM-19/4

Started On : 09/05/2008; Ended On : 09/05/2008 G.W.T: 7.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
			Brownish Very Stiff Silty Clay	1.50	8	11	15	26		V.Stiff	SS
				3.00	5	9	16	25		V.Stiff	SS
				4.50	7	12	15	27		V.Stiff	SS
				6.00	UDS Collected					V.Stiff	SS
7.00										**G.W.T**	
			Brownish Medium Dense Silty Clayey Fine Sand	7.50	5	10	16	26		M.Dense	SS
				9.00	7	11	15	26		M.Dense	SS
10.50				10.50	9	14	18	32		Dense	SS
12.00			Brownish Dense Silty Fine Sand	12.00	8	15	16	31		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-19/4 Location

IR KM 19/4 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-19/4 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	26	UDS	Silty Clay	28	79	33	46	1.1	2.66	0.74	19	44	75	V.Stiff	0	0	0	0	20	80	170.9	12.7	-	-	173.3	0.62	CH
6.00-10.50	26	SS	Silty Clayey Sand	11	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	67	21	12	-	-	21.2	33.4	-	-	SM
10.50-12.00	32	SS	Silty Sand	8	-	-	-	-	2.65	-	18	-	-	Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-19/4

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	8.00	7.84	67.40	70.3

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 7.00m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	7.00m
SPT of the layer	26
Consistency	Very Stiff
Undrained Cohesion, Cu	173.33kPa

* **Layer-2 (from 7.00m to 10.50m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.55 Deg.

The ground water table was encountered at a depth of 7.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic fine-grained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.50	27	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

The details of the computations are annexed to this report.

IR KM 19/4 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
4. **The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.**
5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 19/4 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	26	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	173.33	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	19.00	kN/m^3
Effective Overburden pressure at foundation level (q)	22.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 1158.21 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 463.29 kPa

Limited to an allowable bearing pressure per running meter width: 270.00 kPa

2 Settlements

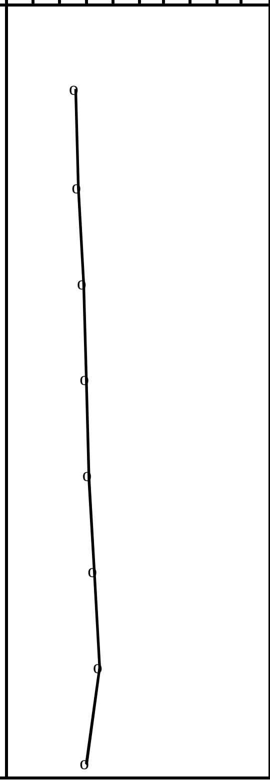
Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 270kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 270kPa and SPT of 26 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 20/5 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 08/05/2008; Ended On : 08/05/2008 G.W.T: 5.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
			Brownish Medium Dense Silty Fine Sand	1.50	7	12	13	25		M.Dense	SS
				3.00	6	10	16	26		M.Dense	SS
				4.50	8	13	15	28		M.Dense	SS
G.W.T				6.00	7	15	14	29		M.Dense	SS
				7.50	9	13	17	30		M.Dense	SS
9.00				9.00	8	14	18	32		Dense	SS
			Brownish Dense Silty Fine Sand	10.50	10	16	18	34		Dense	SS
12.00				12.00	9	12	17	29		M.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-20/5 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-20/5 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	28	SS	Silty Sand	10	-	-	-	-	2.65	-	17	-	-	M.Dense	0	0	0	63	37	0	-	-	21.5	34.2	-	-	SM
9.00-12.00	33	SS	Silty Sand	8	-	-	-	-	2.64	-	18	-	-	Dense	0	0	0	61	39	0	-	-	28.6	35.9	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-20/5

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.91	20.00	33.54

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	28
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.40 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.825 Deg.

The ground water table was encountered at a depth of 5.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	25	47

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 20/5 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 20/5 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	25	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	34.50	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 31.81

N_γ = 45.47

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 627.44 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 250.98 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 25 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 21/3 - 21/4 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 10/05/2008; Ended On : 10/05/2008 G.W.T: 12.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
2.50			Brownish Very Stiff Silty Clay	1.50	4	7	10	17		V.Stiff	SS
			Brownish Stiff Silty Clay	3.00	3	5	9	14		Stiff	SS
				4.50	UDS Collected					Stiff	UDS
				6.00	4	6	6	12		Stiff	SS
				7.50	6	7	8	15		Stiff	SS
9.00				9.00	8	9	13	22		V.Stiff	SS
			Brownish Very Stiff Silty Clay	10.50	9	12	15	27		V.Stiff	SS
12.00				12.00	8	12	18	30		V.Stiff	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-21/3-21/4 Location

IR KM 21/3 - 21/4 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-21/3 to 21/4 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-2.50	17	SS	Silty Clay	30	75	30	45	1.0	2.66	0.80	17	30	66	V.Stiff	0	0	0	0	22	78	-	-	113.1	12.9	113.3	0.59	CH
2.50-9.00	14	**SS, UDS**	Silty Clay	28	77	25	52	0.9	2.68	0.8	16	-	-	Stiff	0	0	0	0	21	79	91.7	14.3	-	-	93.3	0.60	CH
9.00-12.00	24	SS	Silty Clay	21	81	28	53	1.1	2.65	0.6	18	-	-	V.Stiff	0	0	0	0	18	82	-	-	-	-	160.0	0.64	CH

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-21/3 to 21/4

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.80	59.30	88.10

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

*** Layer-1 (from E.G.L to 2.50m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.50m
SPT of the layer	17
Consistency	Very Stiff
Undrained Cohesion, Cu	113.33kPa

*** Layer-2 (from 2.50m to 9.00m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	6.50m
SPT of the layer	14
Consistency	Stiff
Undrained Cohesion, Cu	93.33kPa

*** Layer-3 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	24
Consistency	Very Stiff
Undrained Cohesion, Cu	160.00kPa

The ground water table was encountered at a depth of 12.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

If such type of fine-grained strata is considered as bearing strata, the foundation system shall either be coupled with ground replacement technique or located below the zone of **desiccation i.e. dry up** (Normally the zone of desiccation extends up to a maximum depth of 2.50m below the existing ground level).

As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without any ground improvement

technique

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of highly plastic fine-grained strata.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.

The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.50	20	46

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

The details of the computations are annexed to this report.

IR KM 21/3 - 21/4 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content but are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located below the zone of desiccation i.e. at a depth where the volumetric change phenomenon of the bearing strata corresponding to variations in seasonal moisture content becomes zero. Hence, the foundation system can be located at a depth of 2.50m below the natural ground level.
3. As the sub-surface strata encountered at the investigation locations at shallow depths are fine-grained type met in the form of highly plastic silty clay, the safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
4. **The safe bearing capacity of proposed foundation system at a recommended depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.**
5. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 21/3 - 21/4 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	14	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	93.33	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	15.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 623.65 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 249.46 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 14 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 22/5 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 09/05/2008; Ended On : 09/05/2008 G.W.T: 5.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Loose to Medium Dense Silty Fine Sand	1.50	6	6	9	15		Loose	SS
				3.00	5	7	10	17		M.Dense	SS
				4.50	6	7	9	16		M.Dense	SS
G.W.T				6.00	7	7	8	15		Loose	SS
7.50				7.50	7	11	15	26		V.Stiff	SS
			Greyish Very Stiff Silty Clay mixed with Kankars	9.00	UDS Collected					V.Stiff	SS
				10.50	10	13	16	29		V.Stiff	UDS
12.00				12.00	9	11	15	26		Hard	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-22/5 Location

IR KM 22/5 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-22/5 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-7.50	16	SS	Silty Sand	10	-	-	-	-	2.66	-	16	-	-	M.Dense	0	0	0	78	22	0	16.5	31.2	-	-	-	-	SM
7.50-12.00	28	**SS, UDS**	Silty Clay mixed with Kankars	24	70	35	35	1.3	2.65	0.64	19	-	-	V.Stiff	17	0	0	0	21	62	-	-	185.3	18.5	186.6	0.54	CH

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-22/5

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.82	40.80	74.3

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	16
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	31.80 Deg.

* **Layer-2 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Clay mixed with Kankars
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	28
Consistency	Very Stiff
Undrained Cohesion, Cu	186.67kPa

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.20m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.20m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.20	20	40

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 22/5 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.20m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.20m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 22/5 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.20	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.20	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	15	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	31.50	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	13.20	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 22.87

N_γ = 30.09

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 512.81 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 205.12 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

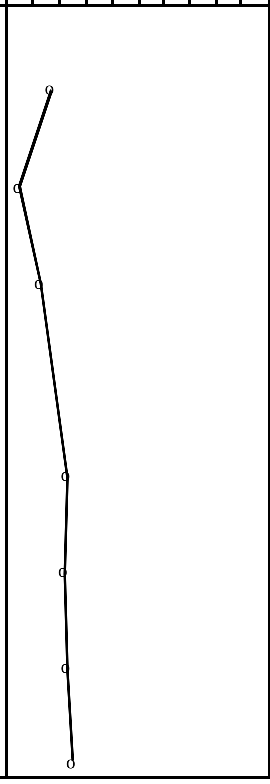
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 15 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 23/1 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 10/05/2008; Ended On : 10/05/2008 G.W.T: 3.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
			Brownish Medium Dense Silty Fine Sand	1.50	7	7	10	17		M.Dense	SS
2.50	G.W.T		Greyish Loose Sandy Clayey silt	3.00	2	2	2	4		Loose	SS
				4.50	4	6	6	12		Loose	SS
6.50				6.00	UDS Failed					Loose	SS
			Brownish to Greyish Medium Dense Sandy Clayey Silt	7.50	6	9	13	22		M.Dense	SS
				9.00	5	9	12	21		M.Dense	SS
				10.50	7	9	13	22		M.Dense	SS
12.00				12.00	6	10	14	24		M.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-23/1 Location

IR KM 23/1 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-23/1 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-2.50	17	SS	Silty Sand	11	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	71	29	0	-	-	23.1	31.9	-	-	SM
2.50-6.50	8	**SS, UDS**	Sandy Clayey Silt	17	33	14	19	0.8	2.68	-	14	-	-	Loose	0	0	0	11	55	34	16.6	28.1	-	-	-	-	SM
6.50-12.00	21	SS	Sandy Clayey Silt	14	27	15	12	1.1	2.66	-	17	-	-	M.Dense	0	0	0	15	59	26	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-23/1

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.81	59.50	89.3

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 2.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	2.50m
SPT of the layer	17
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	32.10 Deg.

* **Layer-2 (from 2.50m to 6.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Greyish
Thickness of Layer	4.00m
SPT of the layer	08
Relative Density	Loose
Angle of Shearing Resistance, ϕ	29.60 Deg.

* **Layer-3 (from 6.50m to 12.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish to Greyish
Thickness of Layer	5.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.30 Deg.

The ground water table was encountered at a depth of 3.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended MAXIMUM Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	16	32

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

Considering the weak sub-soil strata lying underneath the recommended bearing stratum, the maximum depth of the foundation system is recommended above. In no case, the recommended depth shall be increased further.

The details of the computations are annexed to this report.

IR KM 23/1 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. ***Considering the weak sub-soil strata lying underneath the recommended bearing stratum, the maximum depth of the foundation system is recommended above. In no case, the recommended depth shall be increased further.***

6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

8. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 23/1 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	17	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.10	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	9.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 24.66

N_γ = 33.16

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 421.16 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	168.46	kPa
Limited to an allowable bearing pressure per running meter width:	160.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 160kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 160kPa and SPT of 17 are computed to be in the order of 32mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 24 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 11/05/2008; Ended On : 11/05/2008 G.W.T: 10.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SP	Relative Density/Consistency	Type of Sample
									## 10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Medium Dense Silty Clayey Fine Sand	1.50	7	9	10	19		M.Dense	SS
				3.00	8	10	13	23		M.Dense	SS
				4.50	6	11	16	27		M.Dense	SS
				6.00	UDS Collected					M.Dense	**UDS**
				7.50	12	10	13	23		M.Dense	SS
9.00				9.00	12	15	17	32		Hard	SS
G.W.T			Greyish to Brownish Very Stiff to Hard Silty Clay mixed with Kankars	10.50	8	11	19	30		V.Stiff	SS
12.00				12.00	13	16	20	36		Hard	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-24 Location

IR KM 24 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-24 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	23	SS, UDS	Silty Sand	8	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	79	21	0	11.9	32.7	-	-	-	-	SM
9.00-12.00	32	SS	Silty Clay mixed with Kankars	22	75	31	44	1.2	2.65	-	20	-	-	V.Stiff	19	0	0	0	17	64	-	-	-	-	213	0.59	CH

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-24

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.00	7.84	21.30	80.11

IR KM 24 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.90 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Clay mixed with Kankars
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	32
Consistency	Hard
Undrained Cohesion, Cu	213.33kPa

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/ Raft	1.50	20	40

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 24 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 24 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	19	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.70	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 26.45

N_γ = 36.24

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 515.01 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 206.00 kPa

Limited to an allowable bearing pressure per running meter width: 200.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 19 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 25 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 12/05/2008; Ended On : 12/05/2008 G.W.T: 9.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
1.70			Filled Up Soil	1.50	SPT Neglected for the fill Layer					-	DS
			Brownish Stiff Silty Clay	3.00	4	5	7	12		Stiff	SS
				4.50	UDS Collected					Stiff	UDS
				6.00	4	6	9	15		Stiff	SS
				7.50	6	6	7	13		Stiff	SS
9.00				9.00	5	7	10	17		M.Dense	SS
G.W.T 10.50			Greyish Medium Dense Silty Fine Sand	10.50	11	15	19	34		Dense	SS
12.00			Greyish to Brownish Dense Silty Fine Sand	12.00	6	10	25	35		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-25 Location

IR KM 25 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-25 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-1.70	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.70-9.00	13	**SS, UDS**	Silty Clay	33	80	21	59	0.8	2.68	0.9	16	65	53	Stiff	0	0	0	0	21	79	81.4	8.7	-	-	86.0	0.63	CH
9.00-10.50	17	SS	Silty Sand	9	-	-	-	-	2.67	0.2	16	-	-	M.Dense	0	0	0	81	19	0	-	-	13.2	30.9	-	-	SM
10.50-12.00	34	SS	Silty Sand	7	-	-	-	-	2.65	0.2	18	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-25

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.79	100.84	154.83

IR KM 25 (KHURJA - HAFIZPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 1.70m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	1.70m

*** Layer-2 (from 1.70m to 9.00m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	7.30m
SPT of the layer	13
Consistency	Stiff
Undrained Cohesion, Cu	86.67kPa

*** Layer-3 (from 9.00m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	17
Relative Density	Medium Dense
Angle of Shearing Resistance	32.10^{o}

*** Layer-4 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	1.50m
SPT of the layer	34
Relative Density	Dense
Angle of Shearing Resistance	37.10^{o}

IR KM 25 (KHURJA - HAFIZPUR SECTION)

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately below the filled up soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

As the thickness of fill is 1.70m, the foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L) i.e. 4.20m below the existing ground level.

Hence, the foundation system can be raft located at a depth of 4.20m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	2.50	18	62

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 25 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. As the thickness of fill is 1.70m, the foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L) i.e. 4.20m below the existing ground level.
3. The foundation system can be raft located at a depth of 4.20m below the existing ground level (E.G.L).
4. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
5. **The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
6. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
7. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
8. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
9. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

10. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 25 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	4.20	m
Observed Maximum thickness of Filled up Soil:	1.70	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	12	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	80.00	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	15.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 534.56 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	213.82	kPa
Limited to an allowable bearing pressure per running meter width:	180.00	kPa

2 Settlements

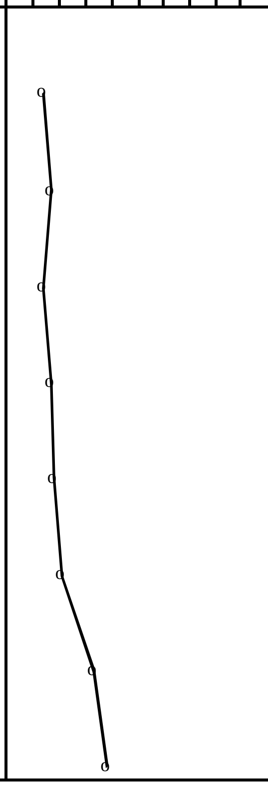
Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 180kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 180kPa and SPT of 12 are computed to be in the order of 62mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

IR KM 26/3 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 12/05/2008; Ended On : 12/05/2008 G.W.T: 10.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
2.00			Brownish Loose Sandy Silt	1.50	4	6	7	13		Loose	SS
			Brownish Medium Dense Sandy Clayey Silt	3.00	4	7	9	16		M.Dense	SS
				4.50	5	5	8	13		Loose	SS
				6.00	5	8	8	16		M.Dense	SS
				7.50	6	7	10	17		M.Dense	SS
10.00				9.00	5	9	11	20		M.Dense	SS
			Greyish to Brownish Medium Dense Silty Fine Sand	10.50	9	14	19	33		Dense	SS
12.00				12.00	10	16	22	38		Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.26/3 Location

IR KM 26/3 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 26/3 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-2.00	13	SS	Sandy Silt	14	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	21	65	14	-	-	-	-	-	-	SM
2.00-10.00	16	SS	Sandy Clayey Silt	12	-	-	-	-	2.7	-	16	-	-	M.Dense	0	0	0	22	58	20	-	-	18.7	31.2	-	-	SM
10.00-12.00	33	SS	Silty Sand	9	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	80	20	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 26/3

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.81	101.32	100.46

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 2.00m depth below)**

Type of Strata	Sandy Silt
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 2.00m to 10.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	8.00m
SPT of the layer	16
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	31.80 Deg.

* **Layer-3 (from 10.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	2.00m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.825 Deg.

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	19	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 26/3 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 26/3 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	16	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	31.80	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 23.76

N_γ = 31.63

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	497.23	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	198.89	kPa
Limited to an allowable bearing pressure per running meter width:	190.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 16 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 27/4 - 27/3 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 13/05/2008; Ended On : 13/05/2008 G.W.T: 9.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Greyish to Brownish Stiff Silty Clay	1.50	4	5	4	9		Stiff	SS
				3.00	4	7	8	15		Stiff	SS
				4.50	5	7	8	15		Stiff	SS
6.00				6.00	5	8	9	17		V.Stiff	SS
			Greyish to Brownish Very Stiff Silty Clay	7.50	5	8	11	19		V.Stiff	SS
9.00				9.00	6	11	13	24		M.Dense	SS
G.W.T			Greyish to Brownish Medium Dense Silty Clayey Fine Sand	10.50	8	12	17	29		M.Dense	SS
12.00				12.00	9	15	22	37		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.27/4-27/3 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-27/4-27/3 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	13	**SS, UDS**	Silty Clay	38	78	27	51	0.8	2.68	1.02	16	70	55	Stiff	0	0	0	0	24	76	80.9	8.7	-	-	86.7	0.61	CH
6.00-9.00	18	SS	Silty Clay	31	77	33	44	1.0	2.66	0.82	18	-	-	V.Stiff	0	0	0	0	22	78	-	-	-	-	120.0	0.60	CH
9.00-12.00	26	SS	Silty Sand	7	-	-	-	-	2.66	0.19	17	-	-	M.Dense	0	0	0	79	13	8	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-27/4-27/3

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.78	120.94	150.03

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Silty Clay
Colour	Greyish to Brownish
Thickness of Layer	6.00m
SPT of the layer	13
Consistency	Stiff
Undrained Cohesion, Cu	86.67kPa

* **Layer-2 (from 6.00m to 9.00m depth below)**

Type of Strata	Silty Clay
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	18
Consistency	Very Stiff
Undrained Cohesion, Cu	120.00kPa

* **Layer-3 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance	34.80^{o}

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	2.50	18	62

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 27/4 - 27/3 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 27/4 - 27/3 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	12	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	80.00	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	15.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	534.56	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	213.82	kPa
Limited to an allowable bearing pressure per running meter width:	180.00	kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 180kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 180kPa and SPT of 12 are computed to be in the order of 62mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

IR KM 28 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 14/05/2008; Ended On : 14/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Greyish to Brownish Very Stiff Silty Clay	1.50	4	7	9	16		V.Stiff	SS
				3.00	6	8	11	19		V.Stiff	SS
				4.50	7	7	10	17		V.Stiff	SS
				6.00	UDS Collected					V.Stiff	SS
				7.50	5	7	9	16		V.Stiff	SS
				9.00	7	10	10	20		V.Stiff	SS
10.50				10.50	8	13	21	34		Dense	SS
12.00			Greyish Dense Silty Fine Sand	12.00	10	17	19	36		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.28 Location

IR KM 28 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-28 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-10.50	18	**SS, UDS**	Silty Clay	28	75	33	42	1.1	2.67	0.7	16	65	48	V.Stiff	0	0	0	0	22	78	114.5	7.8	-	-	120.0	0.59	CH
10.50-12.00	34	SS	Silty Sand	8	-	-	-	-	2.66	0.2	17	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-28

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.80	116.54	134.56

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 10.50m depth below)**

Type of Strata	Silty Clay
Colour	Greyish to Brownish
Thickness of Layer	6.00m
SPT of the layer	18
Consistency	Very Stiff
Undrained Cohesion, Cu	120.00kPa

* **Layer-2 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	34
Relative Density	Dense
Angle of Shearing Resistance	37.10^{o}

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Depth of Foundation System below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	2.50	23	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 28 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 28 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	16	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	106.67	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	15.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 712.75 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	285.10	kPa
Limited to an allowable bearing pressure per running meter width:	230.00	kPa

2 Settlements

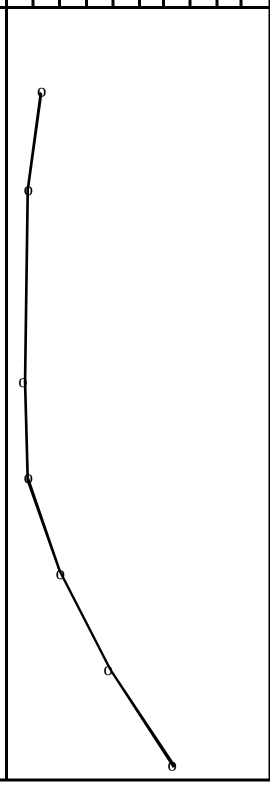
Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 230kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 230kPa and SPT of 16 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

IR KM 28/14 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 14/05/2008; Ended On : 14/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
2.00			Brownish Stiff Silty Clay	1.50	4	7	7	14		Stiff	SS
			Brownish Medium Stiff Silty Clay	3.00	3	3	5	8		M.Stiff	SS
				4.50	UDS Collected					V.Stiff	SS
				6.00	2	3	3	6		Stiff	SS
				7.50	2	3	5	8		M.Stiff	SS
9.00				9.00	6	8	13	21		M.Dense	SS
10.50			Brownish to Greyish Medium Dense Silty Fine Sand	10.50	12	17	22	39		Dense	SS
12.00			Greyish Dense Silty Fine Sand	12.00	18	29	34	63		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.28/14 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-28/14 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test Results		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	ϕ (Deg.)	c (kN/m²)	ϕ (Deg.)			
E.G.L-2.00	14	**SS, UDS**	Silty Clay	26	77	24	53	1.0	2.67	0.69	16	65	48	Stiff	0	0	0	0	24	76	90.2	8.7	-	-	93.3	0.60	CH
2.00-9.00	7	**SS**	Silty Clay	31	80	21	59	0.8	2.68	0.83	15	65	48	M.Stiff	0	0	0	0	21	79	43.2	4.5	-	-	46.7	0.63	CH
9.00-10.50	21	SS	Silty Sand	8	-	-	-	-	2.66	0.21	17	-	-	Dense	0	0	0	80	20	0	-	-	-	-	-	-	SM
10.50-12.00	39	SS	Silty Sand	8	-	-	-	-	2.65	0.21	19	-	-	Dense	0	0	0	76	24	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-28/14

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.82	111.21	131.94

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 2.00m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	14
Consistency	Stiff
Undrained Cohesion, Cu	93.33kPa

* **Layer-2 (from 2.00m to 9.00m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	7.00m
SPT of the layer	07
Consistency	Medium Stiff
Undrained Cohesion, Cu	46.67kPa

* **Layer-3 (from 9.00m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish to Greyish
Thickness of Layer	1.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance	37.10^{o}

* **Layer-4 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	39

Relative Density	Dense
Angle of Shearing Resistance	38.475^{o}

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the second week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Depth of Foundation System below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	2.50	14	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 28/14 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 28/14 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	8	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	53.33	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 356.37 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 142.55 kPa

Limited to an allowable bearing pressure per running meter width: 140.00 kPa

2 Settlements

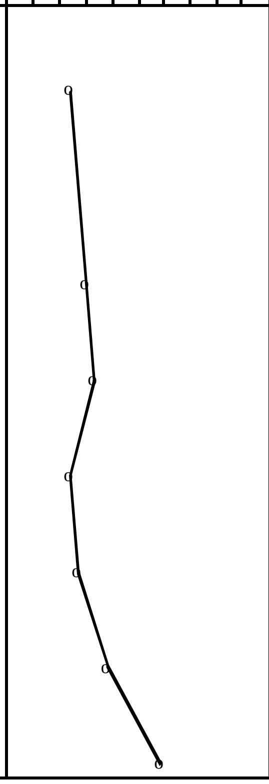
Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 140kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 140kPa and SPT of 08 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

IR KM 30 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 15/05/2008; Ended On : 15/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	SPT - Details 0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
			Brownish Very Stiff Silty Clay	1.50	8	10	13	23		V.Stiff	SS
				3.00	UDS Collected					V.Stiff	SS
				4.50	11	13	16	29		V.Stiff	SS
				6.00	12	15	17	32		Hard	SS
				7.50	8	10	13	23		V.Stiff	SS
				9.00	9	12	14	26		V.Stiff	SS
10.50				10.50	12	17	21	38		Dense	SS
12.00			Greyish Dense Silty Fine Sand	12.00	14	26	33	59		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.30 Location

IR KM 30 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-30 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test Results		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-10.50	27	**SS, UDS**	Silty Clay	21	75	31	44	1.2	2.65	0.6	19	64	45	V.Stiff	0	0	0	0	24	76	175.4	9.8	-	-	180.0	0.59	CH
10.50-12.00	38	SS	Silty Sand	8	-	-	-	-	2.66	0.2	17	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-30

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.88	94.57	100.35

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 10.50m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	10.50m
SPT of the layer	27
Consistency	Very Stiff
Undrained Cohesion, Cu	180.00kPa

* **Layer-2 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	38
Relative Density	Dense
Angle of Shearing Resistance	38.20^o

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	2.50	30	63

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 30 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 30 (KHURJA - HAFIZPUR SECTION)
DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	23	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	153.33	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	19.00	kN/m^3
Effective Overburden pressure at foundation level (q)	22.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 1024.57 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 409.83 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 23 are computed to be in the order of 63mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

IR KM 31 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 16/05/2008; Ended On : 16/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Medium Dense Silty Fine Sand	1.50	8	10	9	19		M.Dense	SS
				3.00	7	10	14	24		M.Dense	SS
				4.50	9	12	14	26		M.Dense	SS
				6.00	8	13	15	28		M.Dense	SS
				7.50	7	12	11	23		M.Dense	SS
				9.00	10	11	16	27		M.Dense	SS
10.50				10.50	12	15	18	33		Dense	SS
12.00			Greyish Dense Silty Fine Sand	12.00	17	28	39	67		V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.31 Location

IR KM 31 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM.31 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-10.50	25	SS	Silty Sand	9	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	81	19	0	-	-	13.2	33.8	-	-	SM
10.50-12.00	33	SS	Silty Sand	7	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 31

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.79	88.65	112.11

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	10.50m
SPT of the layer	25
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.50 Deg.

* **Layer-2 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.825 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	22	44

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 31 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 31 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	19	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.70	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 26.45

N_γ = 36.24

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 557.52 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 223.01 kPa

Limited to an allowable bearing pressure per running meter width: 220.00 kPa

2 Settlements

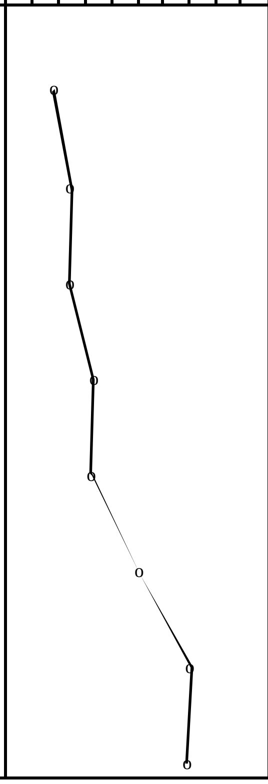
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 19 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 32 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 21/05/2008; Ended On : 21/05/2008 G.W.T: 9.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
				1.50	7	8	10	18		M.Dense	SS
			Brownish Medium Dense Sandy Clayey Silt	3.00	9	11	13	24		M.Dense	SS
				4.50	8	11	13	24		M.Dense	SS
6.00				6.00	14	16	17	33		Dense	SS
			Brownish Dense Sandy Silt	7.50	13	17	15	32		Dense	SS
9.00				9.00	20	24	27	51		V.Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	22	31	39	70		V.Dense	SS
12.00				12.00	20	29	40	69		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.32 Location

IR KM 32 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM.32 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	22	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	23	54	23	-	-	14.5	32.7	-	-	SM
6.00-9.00	32	SS	Sandy Silt	8	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	26	74	0	-	-	-	-	-	-	SM
9.00-12.00	60	SS	Silty Sand	5	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 32

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.81	84.56	104.34

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60 Deg.

* **Layer-2 (from 6.00m to 9.00m depth below)**

Type of Strata	Sandy Silt
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	32
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	36.55 Deg.

* **Layer-3 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	60
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.560 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	21	44

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 32 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 32 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	18	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.40	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 25.55

N_γ = 34.70

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 537.42 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 214.97 kPa

Limited to an allowable bearing pressure per running meter width: 210.00 kPa

2 Settlements

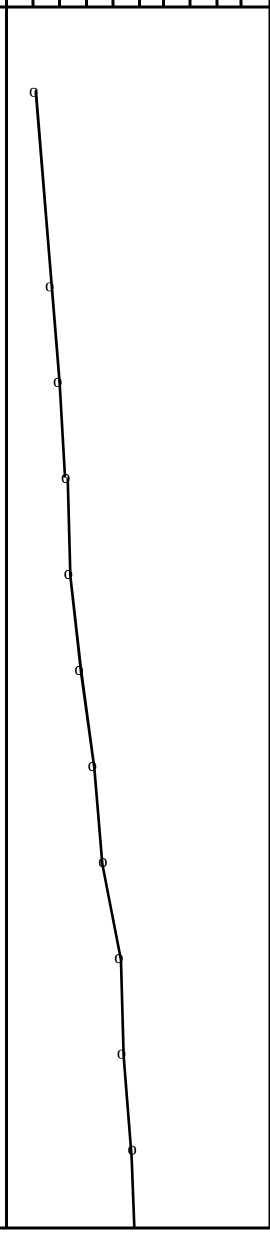
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 210kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 210kPa and SPT of 18 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 33/10-11 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

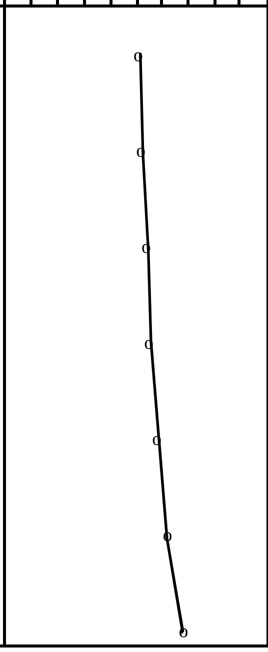
Started On : 16/06/2008; Ended On : 18/06/2008 G.W.T: 5.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
			Brownish Loose Sandy Clayey Silt	1.50	3	4	7	11		Loose	SS
				3.00	UDS Collected					Loose	SS
4.50				4.50	4	6	11	17		M.Dense	SS
G.W.T			Greyish to Brownish Medium Dense Silty Fine Sand	6.00	6	8	12	20		M.Dense	SS
				7.50	7	9	14	23		M.Dense	SS
				9.00	7	10	14	24		M.Dense	SS
				11.00	9	12	16	28		M.Dense	SS
12.50				12.50	11	14	19	33		Dense	SS
			Brownish Dense Silty Fine to Medium Coarse Sand	14.00	12	15	22	37		Dense	DS
				15.50	13	16	26	42		Dense	SS
				17.00	14	16	27	43		Dense	SS
				18.50	14	18	29	47		Dense	SS
19.00											



Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.
Location: At KM.33 (10-11)
Started On : 16/06/2008; Ended On : 18/06/2008 G.W.T: 5.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
			Brownish Dense Silty Fine to Medium Coarse Sand	20.00	15	20	30	50		Dense	SS
22.00				22.00	16	21	30	51		V.Dense	SS
			Greyish Very Dense Silty Fine Sand	23.50	18	21	32	53		V.Dense	SS
				25.00	18	22	32	54		V.Dense	SS
				26.50	19	24	33	57		V.Dense	SS
				28.00	20	26	35	61		V.Dense	SS
30.00				29.50	21	30	37	67		V.Dense	SS



Bore Hole Terminated at a depth of 30.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.33 (10-11) Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-33 (10-11) Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	11	SS	Sandy Clayey Silt	15	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	14	63	23	13.8	29.6	-	-	-	-	SM
4.50-12.50	22	SS	Silty Sand	11	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM
12.50-22.00	45	SS	Silty Sand	7	-	-	-	-	2.7	-	19	-	-	Dense	0	0	20	60	20	0	-	-	-	-	-	-	SM
22.00-30.00	55	SS	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM.33 (10-11)

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.86	50.87	45.86

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	11
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.30 Deg.

* **Layer-2 (from 4.50m to 12.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	8.00m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60 Deg.

* **Layer-3 (from 12.50m to 22.00m depth below)**

Type of Strata	Silty Fine to Medium Coarse Sand
Colour	Brownish
Thickness of Layer	9.50m
SPT of the layer	45
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.875 Deg.

* **Layer-4 (from 22.00m to 30.00m depth below)**

Type of Strata	Silty Fine Sand

Colour	Greyish
Thickness of Layer	8.00m
SPT of the layer	55
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	41.75 Deg.

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the third week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

However, the sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Deep Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level.

Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.

The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented below which can be adopted for foundation design purposes.

IR KM 33/10-11 (KHURJA - HAFIZPUR SECTION)

S.No.	Diameter of Pile (mm)	Safe Load Carrying Capacity (kN)	Safe Pull Out carrying Capacity (kN)	Safe Lateral Load carrying Capacity (kN)
1	1000	12000	6018	600

The details of the computations are annexed to this report.

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths are poor from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. The sub-soil strata encountered at a depth of 30.0m below the existing ground level as refusal strata (SPT>50) can be considered as end bearing strata for the proposed foundation system.
3. The bearing strata of the proposed foundation system can be the sub soil strata encountered at a depth of 30.0m below the existing ground level. Hence, the foundation system can be 30.0m long bored cast-in-situ piles located over refusal strata and drilled though DMC technique.
4. The safe load carrying capacity of 30.0m long bored cast-in-situ pile of 1000mm diameter is computed and presented in Clause 4.2.1 can be adopted for foundation design purposes.
5. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 33/10-11 (KHURJA - HAFIZPUR SECTION)
DESIGN OF PILE FOUNDATION(Refer:BH-01)
Refer, IS:2911(Part I/Sec 2)-1979, Reaffirmed 1997

1.0 Type of Installation of Pile — **Bored Cast in Situ**

1.1 Geometrical Data

Assumed Diameter of pile(D):	**1000.0**	mm
Assumed R.L of E.G.L:	0.000	m
Length of pile below E.G.L.(l) :	**30.000**	m
R.L. of Bot. of Pile	-30.00	m

1.2 Design of Pile for Vertical Compression

1.2.1 Computation of Skin Resistance:

1.2.1.1 **Layer-I**

Type of Strata:	Sandy Clayey Silt	
Average SPT of the strata,N:	12	
Bulk Density of the strata,γ:	15	kN/m^3
Angle of Shearing Resistance,ϕ:	30.6	Deg.
Depth of top of Strata:	0.00	m
Depth of bottom of Strata:	4.50	m
Average Thickness of Strata,I_c:	4.50	m
Effective overburden pressure over the top of strata,σ_{top}:	0.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	22.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	11.25	kN/m^2
Coeff. Of Earth Pressure,k:	1.00	
Skin Resistance of the pile,q_s:	94.06	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.2 **Layer-II**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	22	
Bulk Density of the strata,γ:	17	kN/m^3
Angle of Shearing Resistance,ϕ:	33.6	Deg.
Depth of top of Strata:	4.50	m
Depth of bottom of Strata:	12.50	m
Average Thickness of Strata,I_c:	8.00	m
Effective overburden pressure over the top of strata,σ_{top}:	22.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	78.50	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	50.50	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q_s:	1264.9	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.3 **Layer-III**

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	45	

Bulk Density of the strata,γ:	19	kN/m^3
Angle of Shearing Resistance,ϕ:	39.875	Deg.
Depth of top of Strata:	12.50	m
Depth of bottom of Strata:	22.00	m
Average Thickness of Strata,I_c:	9.50	m
Effective overburden pressure over the top of strata,σ_{top}:	78.50	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	164.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	121.25	kN/m^2
Coeff. Of Earth Pressure,k:	1.50	
Skin Resistance of the pile,q_s:	4534.6	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		

1.2.1.4 Layer-IV

Type of Strata:	Silty Sand	
Average SPT of the strata,N:	55	
Bulk Density of the strata,γ:	20	kN/m^3
Angle of Shearing Resistance,ϕ:	41.75	Deg.
Depth of top of Strata:	22.00	m
Depth of bottom of Strata:	30.00	m
Average Thickness of Strata,I_c:	8.00	m
Effective overburden pressure over the top of strata,σ_{top}:	164.00	kN/m^2
Effective overburden pressure over the bottom of strata,σ_{bottom}:	244.00	kN/m^2
Effective overburden pressure at the middle of the strata,σ_{middle}:	204.00	kN/m^2
Coeff. Of Earth Pressure,k:	2.00	
Skin Resistance of the pile,q_s:	9152.2	kN
(q_s:σ*k*tanϕ*pi()*d*Ic)		
Ultimate Skin Resistance,q_s:	**15045.7**	**kN**

1.2.2 Computation of End Bearing Resistance:

Type of Bearing Strata	Silty Sand	
Cross-Sectional Area of pile,Ap:	0.785	m^2
R.L of bottom of pile:	-30.00	
Minimum SPT-value of the Bearing Strata	67	
Angle of Shearing Resistance(ASR)	42.50	Degrees
Bearing Capacity Factor(Nq)	220.00	
Effecitve Over Burden Pressure at the bottom of pile (q)	100.00	kPa
(limited to a maximum value produced by a soil layer of thickness equal to 20 times the diameter of pile from the N.G.L.)		
Ultimate End Bearing Resistance (Qp)	**17278.8**	**kN**
(Qp=Ap*q*Nq)		

1.3.0

Ultimate Load Carrying Capacity (Qu=Qp+q_p)	**32324.4**	**kN**
Safe Load Carrying Capacity (Qsafe =Qu/2.5)	**12929.8**	**kN**
However, limit Q_{safe} to the structural capacity of pile:	**12000.0**	**kN**

IR KM 35/3 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 16/05/2008; Ended On : 17/05/2008 G.W.T: 10.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	SPT - Details 0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
			Brownish Loose Sandy Clayey Silt	1.50	3	5	6	11		Loose	SS
				3.00	UDS Collected					Loose	SS
				4.50	5	5	6	11		Loose	SS
				6.00	4	7	8	15		M.Dense	SS
7.50				7.50	5	9	10	19		M.Dense	SS
			Greyish to Brownish Medium Dense Silty Fine Sand	9.00	9	12	13	25		M.Dense	SS
G.W.T				10.50	10	12	15	27		M.Dense	SS
12.00				12.00	10	13	16	29		M.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at Bridge No.35/3 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 35/3 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-7.50	12	DS	Sandy Clayey Silt	13	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	21	70	9	-	-	15.6	29.8	-	-	SM
7.50-12.00	24	SS	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 35/3

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.88	124.54	111.32

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at KM- 35/3 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.60 Deg.

*** Layer-2 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	4.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20 Deg.

The ground water table was encountered at a depth of 10.50m within the explored depth of investigation in the first week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	12	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 35/3 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy silt and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 35/3 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	11	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 19.29

N_γ = 23.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 340.59 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	136.24	kPa
Limited to an allowable bearing pressure per running meter width:	120.00	kPa

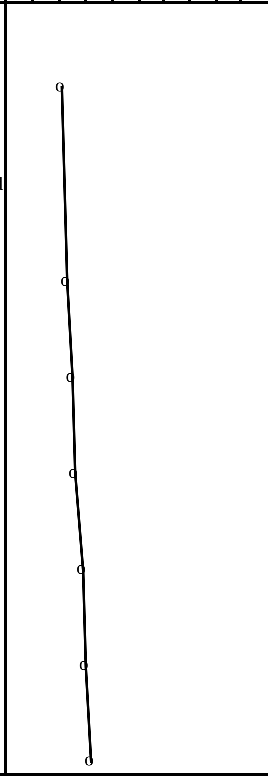
2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 11 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 36 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 20/05/2008; Ended On : 21/05/2008 G.W.T: 9.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Medium Dense Silty Fine Sand	1.50	6	10	11	21		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	6	10	13	23		M.Dense	SS
				6.00	7	11	14	25		M.Dense	SS
				7.50	8	11	15	26		M.Dense	SS
G.W.T				9.00	10	13	16	29		M.Dense	SS
				10.50	10	14	16	30		M.Dense	SS
12.00				12.00	12	15	17	32		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-36 Location

IR KM 36 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM.36 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-12.00	26	SS	Silty Sand	9	-	-	-	-	2.67	-	16	-	-	M.Dense	0	0	0	79	21	0	-	-	12.5	33.9	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 36

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.83	80.98	100.82

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	12.00m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	24	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 36 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 36 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	21	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:	
N_c =	N/A
N_q =	28.23
N_γ =	39.32
Shape Factors:	
S_c =	N/A
S_q =	1.30
S_γ =	1.00
Depth Factors :	
D_c =	N/A
D_q =	1.00
D_γ =	1.00
Inclination Factor:	
I_c =	N/A
I_q =	1.00
I_γ =	1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	680.95	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	272.38	kPa
Limited to an allowable bearing pressure per running meter width:	240.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 21 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 37 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 20/05/2008; Ended On : 21/05/2008 G.W.T: 9.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	SPT - Details 0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
			Brownish Medium Dense Sandy Clayey Silt	1.50	5	10	12	22		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	6	10	14	24		M.Dense	SS
				6.00	8	12	15	27		M.Dense	SS
				7.50	10	13	16	29		M.Dense	SS
9.00				9.00	11	13	18	31		Dense	SS
			Greyish to Brownish Dense Silty Fine Sand	10.50	11	14	20	34		Dense	SS
12.00				12.00	12	14	22	36		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-37 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 37 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)			
E.G.L-9.00	26	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	24	59	17	18.7	34.1	-	-	-	-	SM
9.00-12.00	32	SS	Silty Sand	8	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 37

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.85	89.54	70.93

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	9.00m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.55 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the third week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	24	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 37 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 37 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	22	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.60	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 29.13

N_γ = 40.85

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 703.76 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 281.50 kPa

Limited to an allowable bearing pressure per running meter width: 240.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 22 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 38 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At KM-38

Started On : 24/05/2008; Ended On : 25/05/2008 G.W.T: 7.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
			Brownish Medium Dense Sandy Clayey Silt	1.50	8	10	12	22		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	8	12	13	25		M.Dense	SS
6.00				6.00	10	15	16	31		Dense	SS
	G.W.T		Greyish to Brownish Dense Silty Fine Sand	7.50	11	15	18	33		Dense	SS
				9.00	12	17	19	36		Dense	SS
				10.50	14	20	20	40		Dense	SS
12.00				12.00	15	21	23	44		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-38 Location

IR KM 38 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 38 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	24	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	21	61	18	15.9	33.7	-	-	-	-	SM
6.00-12.00	35	SS	Silty Sand	7	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 38

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.88	80.92	73.41

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20 Deg.

* **Layer-2 (from 6.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	6.00m
SPT of the layer	35
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.375 Deg.

The ground water table was encountered at a depth of 7.00m within the explored depth of investigation in the fourth week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	24	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 38 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 38 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	22	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.60	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 29.13

N_γ = 40.85

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

$Q_u =$ 703.76 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	281.50	kPa
Limited to an allowable bearing pressure per running meter width:	240.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 240kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 240kPa and SPT of 22 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 39 (KHURJA - HAFIZPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At KM-39

Started On : 24/05/2008; Ended On : 25/05/2008 G.W.T: 9.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Medium Dense Sandy Clayey Silt	1.50	5	9	10	19		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	6	10	12	22		M.Dense	SS
				6.00	8	11	14	25		M.Dense	SS
				7.50	8	12	15	27		M.Dense	SS
9.50				9.00	10	14	15	29		M.Dense	SS
			Greyish to Brownish Dense Silty Fine Sand	10.50	12	16	17	33		Dense	SS
12.00				12.00	13	18	18	36		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-39 Location

IR KM 39 (KHURJA - HAFIZPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 39 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.50	24	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	24	64	12	16.7	33.8	-	-	-	-	SM
9.50-12.00	33	SS	Silty Sand	8	-	-	-	-	2.66	-	18	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 39

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.80	132.22	143.31

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 9.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	9.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20 Deg.

* **Layer-2 (from 9.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	1.50m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.825 Deg.

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the fourth week of May 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be

isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	22	46

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 39 (KHURJA - HAFIZPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 39 (KHURJA - HAFIZPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	19	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.70	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 26.45

N_γ = 36.24

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 635.34 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	254.14	kPa
Limited to an allowable bearing pressure per running meter width:	220.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 19 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

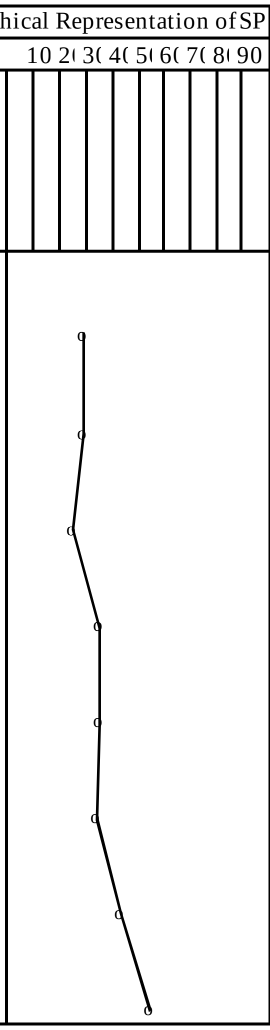
MEERUT – SAHARANPUR SECTION

IR KM 85 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 02/06/2008; Ended On : 02/06/2008 G.W.T: 3.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
			Greyish Medium Dense Silty Fine Sand	1.50	8	13	15	28	M.Dense	SS
G.W.T				3.00	10	12	16	28	M.Dense	SS
				4.50	10	11	13	24	M.Dense	SS
6.00				6.00	13	17	17	34	Dense	SS
			Greyish Dense Silty Fine Sand	7.50	9	14	20	34	Dense	SS
				9.00	8	15	18	33	Dense	SS
				10.50	10	17	26	43	Dense	SS
12.00				12.00	16	23	31	54	V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.85 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-85 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	27	SS	Silty Sand	10	-	-	-	-	2.67	0.27	17	-	-	M.Dense	0	0	0	79	21	0	-	-	16.7	34.6	-	-	SM
6.00-12.00	36	SS	Silty Sand	7	-	-	-	-	2.65	0.19	18	-	-	Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM.85

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	3.00	7.81	90.88	65.56

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	6.00m
SPT of the layer	27
Relative Density	Medium Dense
Angle of Shearing Resistance	35.10^o

*** Layer-2 (from 6.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	6.00m
SPT of the layer	36
Relative Density	Dense
Angle of Shearing Resistance	37.65^o

The ground water table was encountered at a depth of 3.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	30	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 85 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 85 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	28	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	35.40	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 35.77

N_γ = 52.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 876.05 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 350.42 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

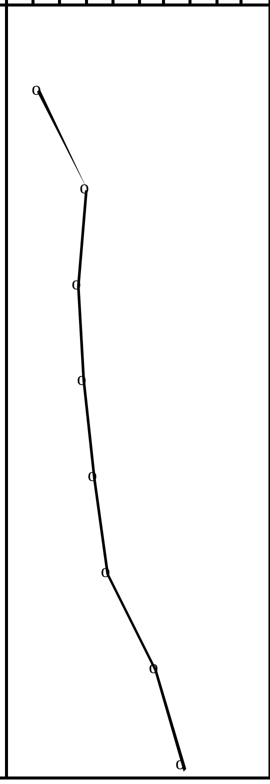
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 28 are computed to be in the order of 48mm which is within the permissible limits of

IR KM 86 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 03/06/2008; Ended On : 03/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
2.00			Brownish Loose Sandy Clayey Silt	1.50	4	6	6	12		Loose	SS
			Greyish to Brownish Medium Dense Silty Fine Sand	3.00	8	12	17	29		M.Dense	SS
				4.50	6	10	16	26		M.Dense	SS
				6.00	12	12	16	28		M.Dense	SS
7.50				7.50	8	15	17	32		Dense	SS
			Greyish Dense Silty Fine Sand	9.00	11	17	20	37		Dense	SS
10.50				10.50	18	24	33	57		V.Dense	SS
12.00			Greyish Very Dense Silty Fine Sand	12.00	20	28	39	67		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.86 Location

IR KM 86 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-86 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	φ (Deg.)	c (kN/m^2)	φ (Deg.)			
E.G.L-2.00	12	SS	Sandy Clayey Silt	10	-	-	-	-	2.68	0.27	15	-	-	Loose	0	0	0	21	65	14	-	-	15.4	29.9	-	-	SM
2.00-7.50	28	SS	Silty Sand	9	-	-	-	-	2.67	0.24	17	-	-	M.Dense	0	0	0	85	15	0	-	-	-	-	-	-	SM
7.50-10.50	34	SS	Silty Sand	8	-	-	-	-	2.66	0.21	18	-	-	Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
10.50-12.00	57	SS	Silty Sand	6	-	-	-	-	2.65	0.16	20	-	-	V.Dense	0	0	0	74	16	10	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM.86

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.79	111.23	78.55

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 2.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	12
Relative Density	Loose
Angle of Shearing Resistance	30.60^o

* **Layer-2 (from 2.00m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	5.50m
SPT of the layer	28
Relative Density	Medium Dense
Angle of Shearing Resistance	35.40^o

* **Layer-3 (from 7.50m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	34
Relative Density	Dense
Angle of Shearing Resistance	37.10^o

* **Layer-4 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m

SPT of the layer	57
Relative Density	Very Dense
Angle of Shearing Resistance	42.05^{o}

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	30	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 86 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 86 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	29	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	35.70	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 37.63

N_γ = 56.62

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*γ*Nγ*Sγ*Dγ*Ig*w'

Q_u = 925.44 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 370.18 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 29 are computed to be in the order of 48mm which is within the permissible limits of

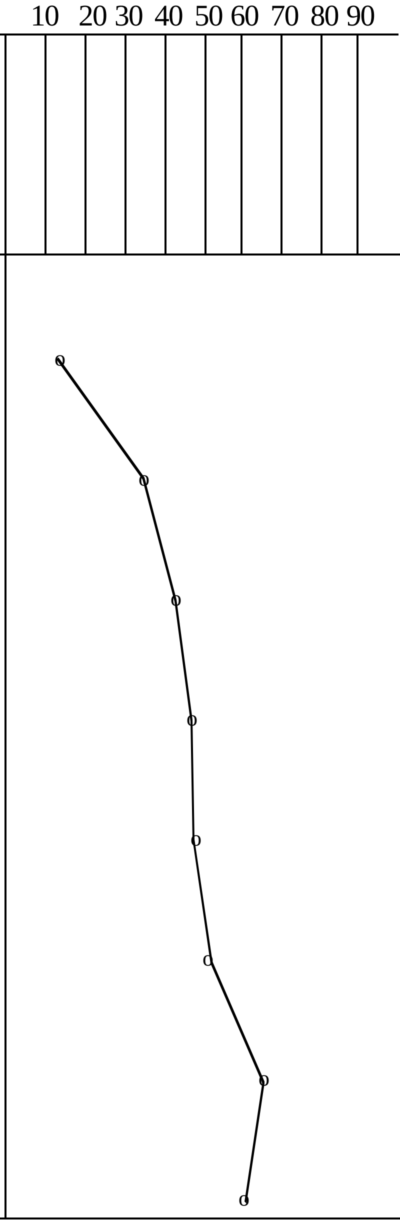
IR KM 89 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 03/06/2008; Ended On : 03/06/2008 G.W.T: 8.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
2.00			Brownish to Greyish Loose Sandy Clayey Silt	1.50	5	6	7	13	Loose	SS
			Greyish Dense Silty Fine Sand	3.00	13	15	19	34	Dense	SS
				4.50	18	20	22	42	Dense	SS
				6.00	20	23	24	47	Dense	SS
G.W.T				7.50	22	24	24	48	Dense	SS
9.00				9.00	25	25	26	51	V.Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	24	27	39	66	V.Dense	SS
12.00				12.00	28	30	31	61	V.Dense	SS

Graphical Representation of SPT



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.89 Location

IR KM 89 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-89 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-2.00	13	SS	Sandy Clayey Silt	12	-	-	-	-	2.68	0.32	15	-	-	Loose	0	0	0	24	67	9	-	-	-	-	-	-	SM
2.00-9.00	43	SS	Silty Sand	8	-	-	-	-	2.67	0.21	19	-	-	Dense	0	0	0	81	19	0	-	-	14.5	38.7	-	-	SM
10.50-12.00	59	SS	Silty Sand	7	-	-	-	-	2.65	0.19	20	-	-	V.Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM.89

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.85	88.65	70.79

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 2.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish to Greyish
Thickness of Layer	2.00m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance	30.90^o

* **Layer-2 (from 2.00m to 9.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	7.00m
SPT of the layer	43
Relative Density	Dense
Angle of Shearing Resistance	39.425^o

* **Layer-3 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	59
Relative Density	Very Dense
Angle of Shearing Resistance	42.35^o

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	2.00	33	46

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 89 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 89 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	34	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	37.10	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	18.00	kN/m^3
Effective Overburden pressure at foundation level (q)	16.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 46.28

N_γ = 73.81

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 1294.73 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 517.89 kPa

Limited to an allowable bearing pressure per running meter width: 330.00 kPa

2 Settlements

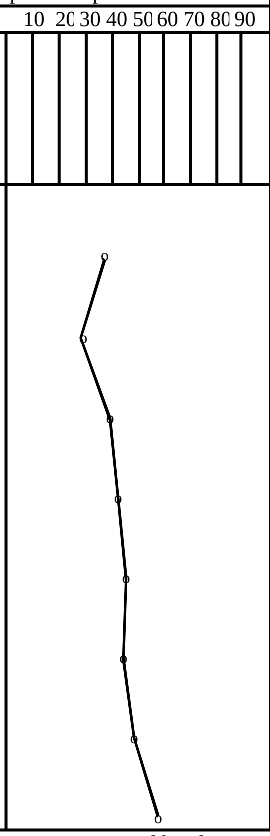
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 330kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 330kPa and SPT of 34 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 90 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.
Started On : 04/06/2008; Ended On : 04/06/2008 G.W.T: 8.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
			Brownish to Yellowish Dense Sandy Clayey Silt	1.50	9	17	19	36	Dense	SS
				3.00	12	14	14	28	M.Dense	SS
4.50				4.50	10	17	21	38	Dense	SS
			Greyish Dense Silty Fine Sand	6.00	12	20	21	41	Dense	SS
				7.50	17	21	23	44	Dense	SS
G.W.T				9.00	20	20	23	43	Dense	SS
				10.50	20	21	26	47	Dense	SS
12.00				12.00	22	24	32	56	V.Dense	SS

Graphical Representation of SPT



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.90 Location

IR KM 90 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-90 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	32	SS	Sandy Clayey Silt	11	-	-	-	-	2.67	0.29	18	-	-	Dense	0	0	0	23	56	21	-	-	18.7	36.0	-	-	SM
4.50-12.00	43	SS	Silty Sand	7	-	-	-	-	2.66	0.19	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Bridge No.03

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.89	88.34	79.56

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance	36.55^o

* **Layer-2 (from 4.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	7.50m
SPT of the layer	43
Relative Density	Dense
Angle of Shearing Resistance	39.425^o

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy silt and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	30	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 90 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and can be considered as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 90 (MEERUT - SAHARANPUR SECTION)
DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	28	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	35.40	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	14.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 35.77

N_γ = 52.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 876.05 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 350.42 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

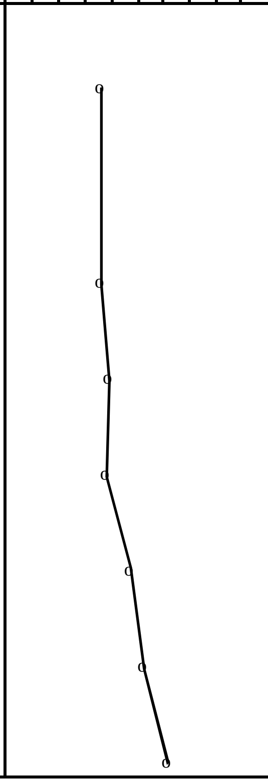
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 28 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 91 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 05/06/2008; Ended On : 05/06/2008 G.W.T: 8.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SP (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
			Brownish Dense Sandy Clayey Silt	1.50	8	15	20	35		Dense	SS
				3.00	UDS Collected					Dense	SS
4.50				4.50	10	16	19	35		Dense	SS
			Greyish Dense Silty Fine Sand	6.00	12	16	22	38		Dense	SS
				7.50	10	17	20	37		Dense	SS
G.W.T				9.00	15	22	24	46		Dense	SS
10.50				10.50	20	24	27	51		V.Dense	SS
12.00			Greyish Very Dense Silty Fine Sand	12.00	22	28	32	60		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.91 Location

IR KM 91 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 91 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	35	SS	Sandy Clayey Silt	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	16	60	24	-	-	16.7	37.1	-	-	SM
4.50-10.50	39	SS	Silty Sand	7	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	78	18	4	-	-	-	-	-	-	SM
10.50-12.00	51	SS	Silty Sand	5	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	72	28	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 91

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.88	70.23	65.67

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location
(As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	35
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.375 Deg.

* **Layer-2 (from 4.50m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	6.00m
SPT of the layer	39
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.475 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	51
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	41.15 Deg.

The ground water table was encountered at a depth of 8.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	30	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 91 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 91 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	35	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	37.38	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	18.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 47.98

N_γ = 77.19

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 1095.78 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	438.31	kPa
Limited to an allowable bearing pressure per running meter width:	300.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 35 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 92 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 04/06/2008; Ended On : 04/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
2.00			Filled Up Soil	1.50	SPT not conducted for the fill layer					-	DS
			Yellowish Medium Dense Sandy Clayey Silt	3.00	8	9	11	20		M.Dense	SS
				4.50	11	13	15	28		M.Dense	SS
6.00				6.00	18	21	22	43		Dense	SS
7.50			Greyish Dense Silty Fine Sand	7.50	21	24	27	51		V.Dense	SS
			Greyish Very Dense Silty Fine Sand	9.00	22	26	25	51		V.Dense	SS
				10.50	22	25	27	52		V.Dense	SS
12.00				12.00	27	31	32	63		V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.92 Location

IR KM 92 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 92 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m³	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m²)	φ (Deg.)	c (kN/m²)	φ (Deg.)			
E.G.L-2.00	-	DS	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.00-6.00	24	SS	Sandy Clayey Silt	11	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	21	55	24	-	-	18.4	33.7	-	-	SM
6.00-7.50	43	SS	Silty Sand	6	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM
7.50-12.00	51	SS	Silty Sand	5	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 92

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.86	98.65	77.54

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 2.00m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	2.00m
SPT of the layer	-

* **Layer-2 (from 2.00m to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Yellowish
Thickness of Layer	4.00m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20 Deg.

* **Layer-3 (from 6.00m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	43
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.425 Deg.

* **Layer-4 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	51
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	41.15 Deg.

IR KM 92 (MEERUT - SAHARANPUR SECTION)

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately below the top filled up soil strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level i.e. 3.50m from the existing ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	1.50	20	44

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 92 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately below the top filled up soil strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level or 3.50m below the existing ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 92 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	3.50	m
Observed Maximum thickness of Filled up Soil:	2.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	20	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.00	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 27.34

N_γ = 37.78

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 533.75 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	213.50	kPa
Limited to an allowable bearing pressure per running meter width:	200.00	kPa

2 Settlements

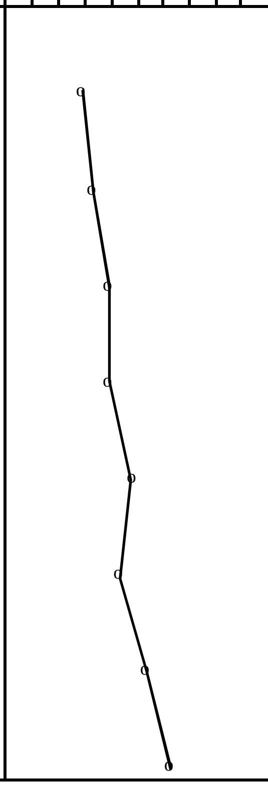
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 20 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 93 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 05/06/2008; Ended On : 05/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
2.00			Brownish Medium Dense Sandy Clayey Silt	1.50	12	13	15	28		M.Dense	SS
			Brownish Dense Silty Fine Sand	3.00	13	15	17	32		Dense	SS
				4.50	15	18	20	38		Dense	SS
				6.00	15	17	21	38		Dense	SS
G.W.T				7.50	17	20	27	47		Dense	SS
				9.00	18	21	21	42		Dense	SS
10.50				10.50	17	22	31	53		V.Dense	SS
12.00			Greyish Very Dense Silty Fine Sand	12.00	28	30	32	62		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.93 Location

IR KM 93 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 93 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-2.00	28	SS	Sandy Clayey Silt	13	-	-	-	-	2.7	-	18	-	-	M.Dense	0	0	0	24	63	13	-	-	17.8	34.9	-	-	SM
2.00-10.50	39	SS	Silty Sand	8	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
10.50-12.00	53	SS	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 93

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.81	100.32	89.44

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 2.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	28
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.40 Deg.

* **Layer-2 (from 2.00m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	8.50m
SPT of the layer	39
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.475 Deg.

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	53
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	41.45 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	25	47

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 93 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 93 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	28	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	35.40	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 35.77

N_γ = 52.94

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 713.28 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	285.31	kPa
Limited to an allowable bearing pressure per running meter width:	250.00	kPa

2 Settlements

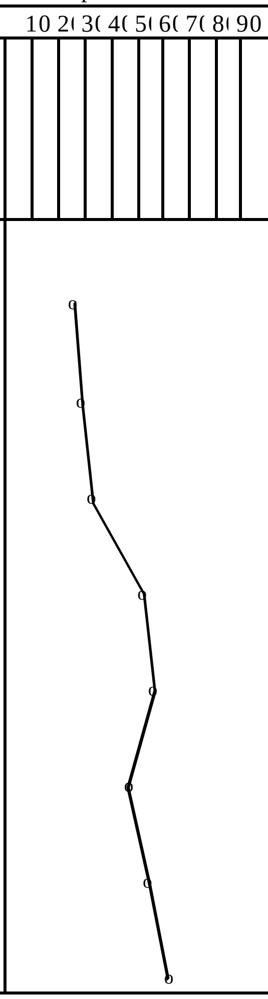
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 28 are computed to be in the order of 47mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 94 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 05/06/2008; Ended On : 05/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP	Relative Density/Consistency	Type of Sample
			Yellowish Very Stiff Silty Clay	1.50	6	8	17	25		V.Stiff	SS
				3.00	8	14	14	28		V.Stiff	SS
4.50				4.50	9	14	18	32		Dense	SS
6.00			Yellowish Dense Silty Fine Sand	6.00	13	24	27	51		V.Dense	SS
G.W.T			Yellowish Very Dense Silty Fine Sand	7.50	15	26	28	54		V.Dense	SS
				9.00	19	22	24	46		Dense	SS
				10.50	18	25	28	53		V.Dense	SS
12.00				12.00	20	30	32	62		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.94 Location

IR KM 94 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-94 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	26	**SS, UDS**	Silty Clay	31	75	34	41	1.1	2.66	0.82	19	67	50	V.Stiff	0	0	0	0	29	71	167.9	14.5	-	-	173.3	0.59	CH
4.50-6.00	32	SS	Silty Sand	8	-	-	-	-	2.66	0.21	18	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
6.00-12.00	51	SS	Silty Sand	5	-	-	-	-	2.65	0.13	20	-	-	V.Dense	0	0	0	72	28	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-94

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.86	100.12	78.66

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Silty Clay
Colour	Yellowish
Thickness of Layer	4.50m
SPT of the layer	26
Consistency	Very Stiff
Undrained Cohesion, Cu	173.33kPa

*** Layer-2 (from 4.50m to 6.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Yellowish
Thickness of Layer	1.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance	36.55^o

*** Layer-3 (from 6.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Yellowish
Thickness of Layer	6.00m
SPT of the layer	51
Relative Density	Very Dense
Angle of Shearing Resistance	41.15^o

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Depth of Foundation System below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	2.50	30	45

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 94 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 94 (MEERUT - SAHARANPUR SECTION)
DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	25	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	166.67	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	19.00	kN/m^3
Effective Overburden pressure at foundation level (q)	22.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 1113.67 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	445.47	kPa
Limited to an allowable bearing pressure per running meter width:	300.00	kPa

2 Settlements

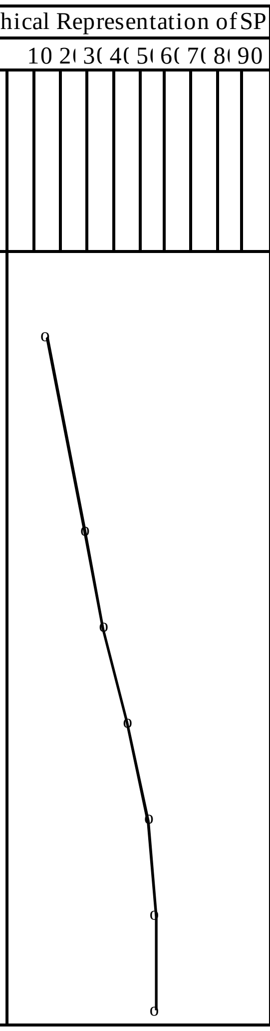
Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 25 are computed to be in the order of 45mm which is within the permissible limits of 50mm for isolated column footings as per I.S:1904.

IR KM 98 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 06/06/2008; Ended On : 06/06/2008 G.W.T: 6.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
			Brownish Stiff Silty Clay	1.50	6	7	7	14	Stiff	SS
				3.00	UDS Collected				Stiff	SS
4.50				4.50	12	14	16	30	M.Dense	SS
6.00			Brownish Medium Dense Sandy Clayey Silt	6.00	13	17	20	37	Dense	SS
			Greyish Very Dense Silty Fine Sand	7.50	12	22	24	46	Dense	SS
9.00				9.00	21	26	28	54	V.Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	23	27	29	56	V.Dense	SS
12.00				12.00	20	26	30	56	V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.98 Location

IR KM 98 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-98 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	14	**SS, UDS**	Silty Clay	36	79	28	51	0.8	2.68	1	16	72	55	Stiff	0	0	0	0	24	76	88.5	11.2	-	-	93.3	0.62	CH
4.50-6.00	30	SS	Silty Sand	9	-	-	-	-	2.67	0.2	18	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
6.00-9.00	42	SS	Silty Sand	7	-	-	-	-	2.65	0.2	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
9.00-12.00	55	SS	Silty Sand	6	-	-	-	-	2.65	0.2	20	-	-	V.Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-98

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.89	78.75	66.49

IR KM 98 (MEERUT - SAHARANPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Silty Clay
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	14
Consistency	Stiff
Undrained Cohesion, Cu	93.33kPa

* **Layer-2 (from 4.50m to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	1.50m
SPT of the layer	30
Relative Density	Medium Dense
Angle of Shearing Resistance	36.00^{o}

* **Layer-3 (from 6.00m to 9.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	42
Relative Density	Dense
Angle of Shearing Resistance	39.20^{o}

* **Layer-4 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	55

Relative Density	Dense
Angle of Shearing Resistance	41.75^{o}

The ground water table was encountered at a depth of 6.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of rafts located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	2.50	20	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 98 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 98 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	14	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	93.33	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	15.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	623.65	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	249.46	kPa
Limited to an allowable bearing pressure per running meter width:	200.00	kPa

2 Settlements

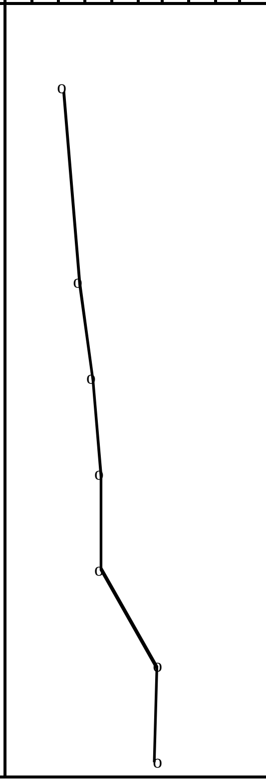
Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 14 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

IR KM 99 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 06/06/2008; Ended On : 06/06/2008 G.W.T: 6.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP: ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
			Greyish Very Stiff Silty Clay	1.50	8	10	12	22		V.Stiff	SS
				3.00	UDS Collected					V.Stiff	SS
4.00											
			Brownish Medium Dense Sandy Clayey Silt	4.50	9	11	17	28		M.Dense	SS
6.00				6.00	10	14	19	33		Dense	SS
			Greyish Dense Silty Fine Sand	7.50	12	17	19	36		Dense	SS
				9.00	12	16	20	36		Dense	SS
10.50				10.50	19	27	32	59		V.Dense	SS
12.00			Greyish Very Dense Silty Fine Sand	12.00	26	27	32	59		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.99 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-99 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.00	22	**SS, UDS**	Silty Clay	34	79	35	44	1	2.66	0.9	18	70	54	V.Stiff	0	0	0	0	25	75	140.2	15.8	-	-	146.7	0.62	CH
4.00-6.00	28	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	0.3	17	-	-	M.Dense	0	0	0	14	66	20	-	-	-	-	-	-	SM
6.00-10.50	35	SS	Silty Sand	7	-	-	-	-	2.66	0.2	18	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
10.50-12.00	59	SS	Silty Sand	5	-	-	-	-	2.65	0.1	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-99

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.88	89.87	76.53

IR KM 99 (MEERUT - SAHARANPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.00m depth below)**

Type of Strata	Silty Clay
Colour	Yellowish
Thickness of Layer	4.50m
SPT of the layer	22
Consistency	Very Stiff
Undrained Cohesion, Cu	146.67kPa

* **Layer-2 (from 4.00m to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	28
Relative Density	Medium Dense
Angle of Shearing Resistance	35.40^{o}

* **Layer-3 (from 6.00m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	35
Relative Density	Dense
Angle of Shearing Resistance	37.375^{o}

* **Layer-4 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	59

Relative Density	Very Dense
Angle of Shearing Resistance	42.20^{o}

The ground water table was encountered at a depth of 6.00m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	2.50	30	49

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 99 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 99 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	22	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	146.67	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	18.00	kN/m^3
Effective Overburden pressure at foundation level (q)	20.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 980.03 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 392.01 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

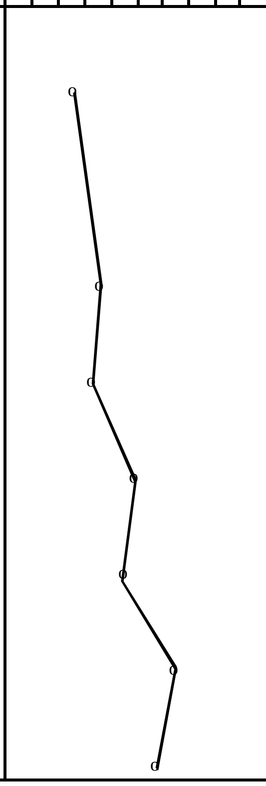
Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 22 are computed to be in the order of 49mm which is within the permissible limits of 50mm for isolated column footings as per I.S:1904.

IR KM 100 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 07/06/2008; Ended On : 07/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP ## 10 2(3(4(5(6(7(8(90	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Greyish Very Stiff Silty Clay	1.50	10	12	14	26		V.Stiff	SS
				3.00	UDS Collected					V.Stiff	SS
4.00											
			Brownish Dense Sandy Clayey Silt	4.50	10	17	18	35		Dense	SS
				6.00	12	15	17	32		Dense	SS
7.50				7.50	11	23	25	48		Dense	SS
			Greyish to Brownish Dense Silty Fine Sand	9.00	12	21	23	44		Dense	SS
10.50				10.50	22	31	34	65		V.Dense	SS
12.00			Greyish Very Dense Silty Fine Sand	12.00	24	28	30	58		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.100 Location

IR KM 100 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-100 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.00	26	**SS, UDS**	Silty Clay	27	75	33	42	1.1	2.65	0.7	19	68	55	V.Stiff	0	0	0	0	24	76	####	18.7	-	-	173.3	0.59	CH
4.00-7.50	33	SS	Sandy Clayey Silt	8	-	-	-	-	2.66	0.2	18	-	-	Dense	0	0	0	21	64	15	-	-	-	-	-	-	SM
7.50-10.50	46	SS	Silty Sand	6	-	-	-	-	2.66	0.2	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
10.50-12.00	65	SS	Silty Sand	5	-	-	-	-	2.65	0.1	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-100

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.85	111.23	89.75

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.00m depth below)**

Type of Strata	Silty Clay
Colour	Greyish
Thickness of Layer	4.00m
SPT of the layer	26
Consistency	Very Stiff
Undrained Cohesion, Cu	173.33kPa

* **Layer-2 (from 4.00m to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	33
Relative Density	Dense
Angle of Shearing Resistance	36.825^{o}

* **Layer-3 (from 7.50m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	3.00m
SPT of the layer	46
Relative Density	Dense
Angle of Shearing Resistance	40.10^{o}

* **Layer-4 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	65

Relative Density	Very Dense
Angle of Shearing Resistance	42.50^{o}

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Depth of Foundation System below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	2.50	33	46

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 100 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of isolated column footing located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for isolated column footings as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 100 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	26	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	173.33	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	18.00	kN/m^3
Effective Overburden pressure at foundation level (q)	20.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

$Q_u =$ 1158.21 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 463.29 kPa

Limited to an allowable bearing pressure per running meter width: 330.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 330kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 330kPa and SPT of 26 are computed to be in the order of 46mm which is within the permissible limits of 50mm for isolated column footings as per I.S:1904.

IR KM 101 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 07/06/2008; Ended On : 07/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 20 30 40 50 60 70 80 90		
			Brownish Dense Sandy Clayey Silt	1.50	11	17	15	32		Dense	SS
				3.00	UDS Collected					Dense	SS
				4.50	9	12	15	27		Dense	SS
				6.00	15	17	20	37		Dense	SS
7.50				7.50	14	16	16	32		Dense	SS
9.00			Greyish to Brownish Dense Silty Fine Sand	9.00	21	23	28	51		V.Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	21	28	35	63		V.Dense	SS
12.00				12.00	22	27	38	65		V.Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.101 Location

IR KM 101 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 101 Location

					Clay										Sieve Analysis						Triaxial Test		Box Shear				
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I_C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-7.50	32	SS	Sandy Clayey Silt	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	80	20	0	19.8	35.5	-	-	-	-	SM
7.50-9.00	32	SS	Silty Sand	8	-	-	-	-	2.7	-	18	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM
9.00-12.00	57	SS	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 101

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.80	111.12	100.46

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.55 Deg.

* **Layer-2 (from 7.50m to 9.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	1.50m
SPT of the layer	32
Relative Density	Dense
Angle of Shearing Resistance, ϕ	36.55 Deg.

* **Layer-3 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	57
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.05 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the first week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	30	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 101 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 101 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	32	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	36.55	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	18.00	kN/m^3
Effective Overburden pressure at foundation level (q)	12.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 42.88

N_γ = 67.06

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 970.67 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 388.27 kPa

Limited to an allowable bearing pressure per running meter width: 300.00 kPa

2 Settlements

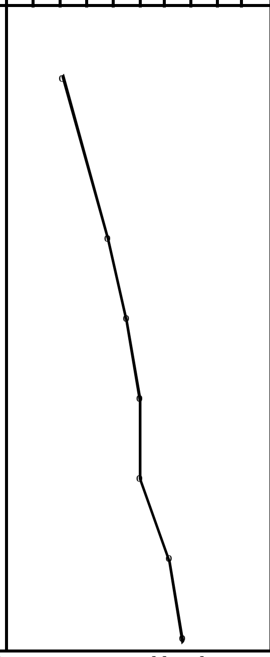
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 300kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 300kPa and SPT of 32 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 102 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 08/06/2008; Ended On : 08/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Medium Dense Sandy Clayey Silt	1.50	9	10	11	21		M.Dense	SS
3.50				3.00	UDS Collected					M.Dense	SS
			Brownish Dense Sandy Clayey Silt	4.50	10	18	20	38		Dense	SS
				6.00	13	22	23	45		Dense	SS
7.50				7.50	16	23	27	50		Dense	SS
			Greyish Dense Silty Fine Sand	9.00	22	24	26	50		Dense	SS
10.50				10.50	22	30	32	62		V.Dense	SS
12.00			Greyish Very Dense Silty Fine Sand	12.00	15	33	34	67		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.102 Location

IR KM 102 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 102 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-3.50	21	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	13	58	29	21.1	32.4	-	-	-	-	SM
3.50-7.50	42	SS	Sandy Clayey Silt	8	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
7.50-10.50	50	SS	Silty Sand	7	-	-	-	-	2.65	-	20	-	-	Dense	0	0	0	75	25	0	-	-	-	-	-	-	SM
10.50-12.00	62	SS	Silty Sand	6	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 102

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.83	91.42	76

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 3.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	21
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.30 Deg.

*** Layer-2 (from 3.50m to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	42
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.20 Deg.

*** Layer-3 (from 7.50m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	50
Relative Density	Dense
Angle of Shearing Resistance, ϕ	41.00 Deg.

*** Layer-4 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m

SPT of the layer	62
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	20	44

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 102 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 102 (MEERUT - SAHARANPUR SECTION)
DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	21	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.30	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 28.23

N_γ = 39.32

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 552.49 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	220.99	kPa
Limited to an allowable bearing pressure per running meter width:	200.00	kPa

2 Settlements

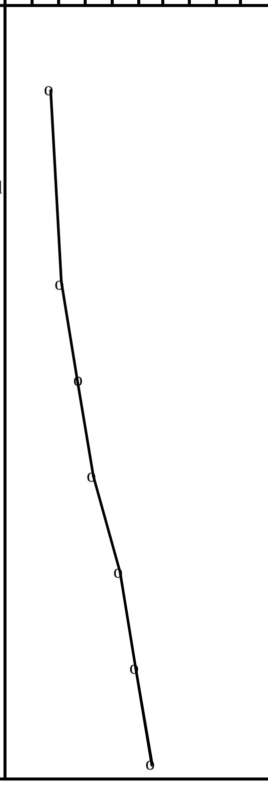
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 200kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 200kPa and SPT of 21 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 103 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 12/06/2008; Ended On : 13/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 20 30 40 50 60 70 80 90		
			Brownish Medium Dense Silty Fine Sand	1.50	6	8	10	18		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	6	10	11	21		M.Dense	SS
				6.00	7	11	17	28		M.Dense	SS
7.50				7.50	10	13	20	33		Dense	SS
			Brownish Dense Silty Fine Sand	9.00	12	18	24	42		Dense	SS
				10.50	16	22	26	48		Dense	SS
12.00				12.00	20	25	29	54		Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-103 Location

IR KM 103 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-103 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-7.50	22	SS	Silty Sand	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	81	19	0	17.8	32.5	-	-	-	-	SM
7.50-12.00	41	**SS, UDS**	Silty Sand	8	-	-	-	-	2.65	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-103

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.81	78.66	89.43

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60 Deg.

* **Layer-2 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	41
Relative Density	Dense
Angle of Shearing Resistance, ϕ	38.975 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.80m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 1.80m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	**Type of Foundation Structure**	**Recommended Minimum Depth of Footing below N.G.L (m)**	**Safe Bearing Capacity (t/m^2)**	**Elastic Settlements (mm)**
1	Isolated Column Footing/Raft	1.80	19	46

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 103 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.80m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.80m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 103 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.80	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.80	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	18	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.40	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.80	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 25.55

N_γ = 34.70

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 497.56 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 199.02 kPa

Limited to an allowable bearing pressure per running meter width: 190.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 190kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 190kPa and SPT of 18 are computed to be in the order of 46mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

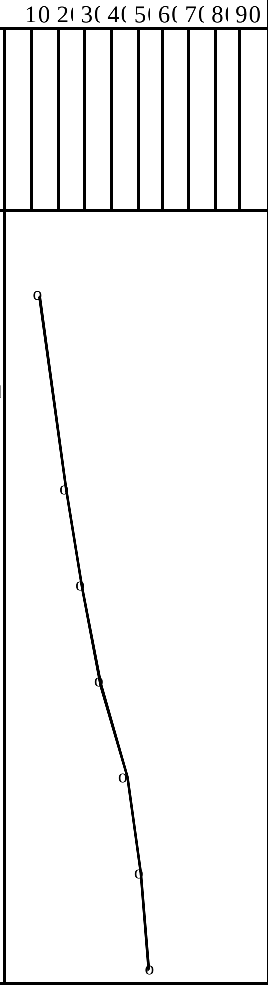
IR KM 104 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 11/06/2008; Ended On : 12/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
			Brownish Loose Silty Fine Sand	1.50	4	6	7	13	Loose	SS
				3.00	UDS Sampler Installed				Loose	UDS
4.50				4.50	7	9	13	22	M.Dense	SS
			Brownish Medium Dense Silty Fine Sand	6.00	7	11	17	28	M.Dense	SS
7.50				7.50	10	14	21	35	Dense	SS
			Greyish to Brownish Dense Silty Fine Sand	9.00	13	19	25	44	Dense	SS
				10.50	17	23	27	50	Dense	SS
12.00				12.00	20	24	30	54	Dense	SS

Graphical Representation of SPT



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-104 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-104 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	13	**SS, UDS**	Silty Sand	13	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	86	14	0	11.2	30.0	-	-	-	-	SM
4.50-7.50	25	**SS**	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
7.50-12.00	43	**SS**	Silty Sand	7	-	-	-	-	2.65	-	19	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-104

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.80	68.76	78

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 4.50m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	25
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.50 Deg.

* **Layer-3 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	4.50m
SPT of the layer	43
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.425 Deg.

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	15	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 104 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	13	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.90	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 21.08

N_γ = 27.01

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 375.37 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 105 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 12/06/2008; Ended On : 13/06/2008 G.W.T: 6.30m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SPT (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Loose Silty Fine Sand	1.50	4	6	7	13		Loose	SS
				3.00	UDS Sampler Installed					Loose	UDS
4.50				4.50	6	9	10	19		M.Dense	SS
			Brownish Medium Dense Silty Fine Sand	6.00	10	11	13	24		M.Dense	SS
G.W.T											
7.50				7.50	12	15	17	32		Dense	SS
			Greyish to Brownish Dense Silty Fine Sand	9.00	15	20	23	43		Dense	SS
				10.50	17	23	27	50		Dense	SS
12.00				12.00	20	24	30	54		Dense	SS

Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-105 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-105 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	13	**SS, UDS**	Silty Sand	13	-	-	-	-	2.7	-	15	-	-	Loose	0	0	0	84	16	0	13.1	28.9	-	-	-	-	SM
4.50-7.50	22	**SS**	Silty Sand	10	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	83	17	0	-	-	-	-	-	-	SM
7.50-12.00	42	**SS**	Silty Sand	7	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-105

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.79	90.49	94.31

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	13
Relative Density	Loose
Angle of Shearing Resistance, ϕ	30.90 Deg.

* **Layer-2 (from 4.50m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	33.60 Deg.

* **Layer-3 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	4.50m
SPT of the layer	42
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.20 Deg.

The ground water table was encountered at a depth of 6.30m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	15	45

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 105 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 105 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	13	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.90	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 21.08

N_γ = 27.01

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 375.37 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 150.15 kPa

Limited to an allowable bearing pressure per running meter width: 150.00 kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 150kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 150kPa and SPT of 13 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

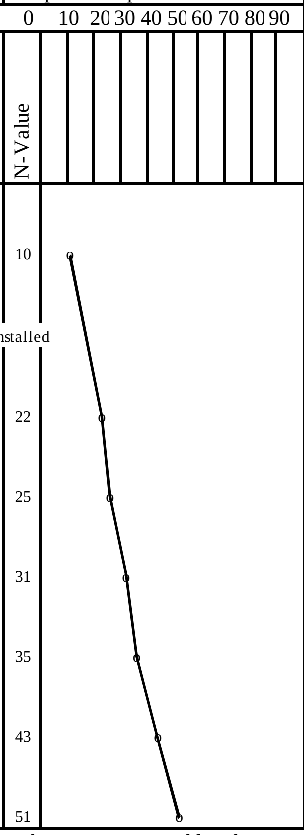
IR KM 106(000-100) (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 13/06/2008; Ended On : 14/06/2008 G.W.T: 7.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Relative Density/Consistency	Type of Sample
			Brownish Loose Silty Fine Sand	1.50	4	4	6	10	-	SS
				3.00	UDS Sampler Installed				Loose	UDS
4.50				4.50	7	10	12	22	M.Dense	SS
			Brownish Medium Dense Silty Fine Sand	6.00	9	11	14	25	M.Dense	SS
7.50				7.50	10	13	18	31	Dense	SS
			Greyish to Brownish Dense Silty Fine Sand	9.00	12	15	20	35	Dense	SS
				10.50	16	20	23	43	Dense	SS
12.00				12.00	16	24	27	51	V.Dense	SS

Graphical Representation of SPT



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-106 (000-100) Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-106 (000-100) Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.50	10	SS	Silty Sand	15	-	-	-	-	2.67	0.4	15	-	-	Loose	0	0	0	91	9	0	-	-	10.9	29.3	-	-	SM
4.50-7.50	23	SS	Silty Sand	10	-	-	-	-	2.66	0.27	17	-	-	M.Dense	0	0	0	84	16	0	-	-	-	-	-	-	SM
7.50-12.00	36	SS	Silty Sand	9	-	-	-	-	2.65	0.24	18	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM.106 (000-100)

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	7.50	7.86	119.35	104.67

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at KM- 106(000-100) Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	10
Relative Density	Loose
Angle of Shearing Resistance	30.00^{o}

* **Layer-2 (from 4.50m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	3.00m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance	33.90^{o}

* **Layer-3 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	4.50m
SPT of the layer	36
Relative Density	Dense
Angle of Shearing Resistance	37.65^{o}

The ground water table was encountered at a depth of 7.50m within the explored depth of investigation in the third week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation system at

a recommended depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	2.00	12	44

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 106(000-100) (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and can be considered as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 2.00m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 2.00m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 106(000-100) (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	10	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	30.00	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 18.40

N_γ = 22.40

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

$Q_u =$ 323.20 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	129.28	kPa
Limited to an allowable bearing pressure per running meter width:	120.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 120kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 120kPa and SPT of 10 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

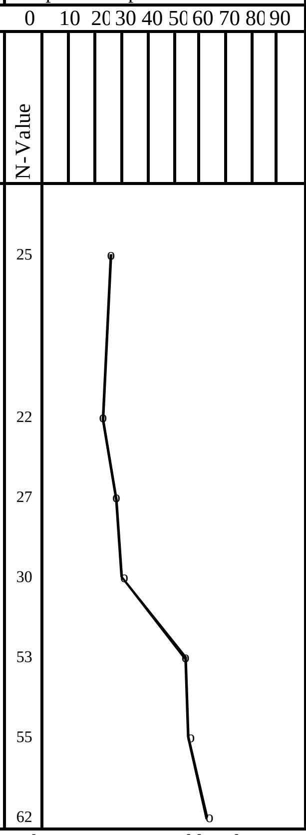
IR KM 108 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 12/06/2008; Ended On : 12/06/2008 G.W.T: 9.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value		
			Brownish Medium Dense Sandy Clayey Silt	1.50	7	11	14	25	M.Dense	SS
				3.00	UDS Collected				M.Dense	SS
				4.50	6	10	12	22	M.Dense	SS
				6.00	12	12	15	27	M.Dense	SS
				7.50	10	13	17	30	M.Dense	SS
9.00				9.00	18	24	29	53	V.Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	20	26	29	55	V.Dense	SS
12.00				12.00	26	30	32	62	V.Dense	SS

Graphical Representation of SPT



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.108 Location

IR KM 108 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 108 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-9.00	26	SS	Sandy Clayey Silt	10	-	-	-	-	2.66	-	18	-	-	M.Dense	0	0	0	26	58	16	19.1	33.9	-	-	-	-	SM
9.00-12.00	54	SS	Silty Sand	8	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 108

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.77	156.54	126.43

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 9.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80 Deg.

* **Layer-2 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	54
Relative Density	Dense
Angle of Shearing Resistance, ϕ	41.60 Deg.

The ground water table was encountered at a depth of 9.00m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	25	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 108 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.

4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.

5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.

6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.

7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 108 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	25	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	34.50	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 31.81

N_γ = 45.47

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 627.44 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 250.98 kPa

Limited to an allowable bearing pressure per running meter width: 250.00 kPa

2 Settlements

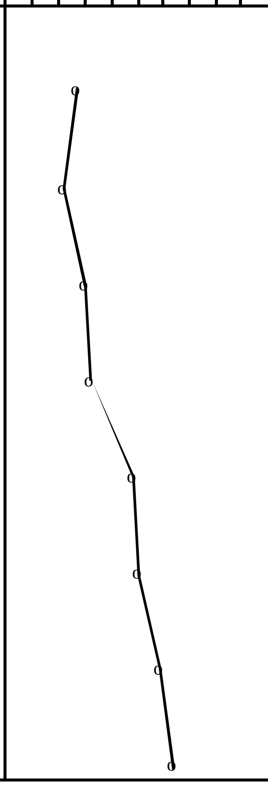
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 25 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 109 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 10/06/2008; Ended On : 10/06/2008 G.W.T: 10.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					Graphical Representation of SP	Relative Density/Consistency	Type of Sample
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	## 10 2(3(4(5(6(7(8(90		
			Brownish Medium Dense Sandy Clayey Silt	1.50	9	12	14	26		M.Dense	SS
				3.00	7	11	10	21		M.Dense	SS
				4.50	11	14	16	30		M.Dense	SS
6.00				6.00	13	15	17	32		Dense	SS
			Greyish Dense Silty Fine Sand	7.50	15	19	28	47		Dense	SS
10.00				9.00	17	23	26	49		Dense	SS
			Greyish Very Dense Silty Fine Sand	10.50	20	27	30	57		V.Dense	SS
12.00				12.00	24	30	32	62		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.109 Location

IR KM 109 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 109 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-6.00	26	SS	Sandy Clayey Silt	11	-	-	-	-	2.7	-	18	-	-	M.Dense	0	0	0	21	55	24	16.5	34.1	-	-	-	-	SM
6.00-10.00	43	SS	Silty Sand	9	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
10.00-12.00	57	SS	Silty Sand	7	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	74	26	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 109

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.89	144.32	121.46

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location

(As presented in the site plan)

* **Layer-1 (from E.G.L to 6.00m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	26
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.80 Deg.

* **Layer-2 (from 6.00m to 10.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.00m
SPT of the layer	43
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.425 Deg.

* **Layer-3 (from 10.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.00m
SPT of the layer	57
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.05 Deg.

The ground water table was encountered at a depth of 10.00m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	25	48

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 109 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 109 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	26	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	34.80	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 32.70

N_γ = 47.00

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_{C}+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	646.18	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	258.47	kPa
Limited to an allowable bearing pressure per running meter width:	250.00	kPa

2 Settlements

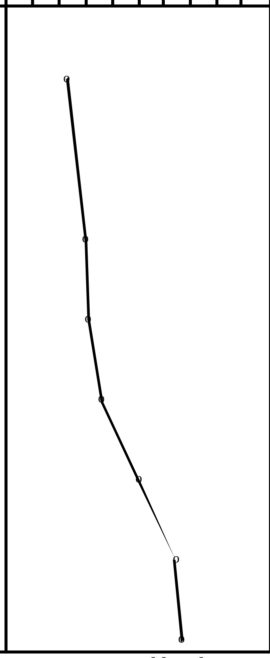
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 26 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 110 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km 156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 12/06/2008; Ended On : 12/06/2008 G.W.T: 9.20m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (0 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
1.60			Filled Up Soil								
			Brownish Medium Dense Silty Clayey Fine Sand	2.00	8	10	12	22		M.Dense	SS
				3.00	UDS Collected					M.Dense	SS
				4.50	10	14	15	29		M.Dense	SS
				6.00	9	13	17	30		M.Dense	SS
7.50				7.50	8	16	19	35		Dense	SS
G.W.T			Greyish Dense Silty Fine Sand	9.00	15	22	28	50		Dense	SS
10.00											
			Greyish Very Dense Silty Fine Sand	10.50	20	29	36	65		V.Dense	SS
12.00				12.00	22	32	35	67		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM.110 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-110 Location

					Clay										Sieve Analysis						Triaxial Test		Box Shear				
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	LL (%)	PL (%)	PI	Consistency, I_C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-1.60	-	**DS**	Filled Up Soil	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.60-7.50	27	**SS, UDS**	Silty Sand	11	-	-	-	-	2.7	-	17	-	-	M.Dense	0	0	0	83	17	0	12.8	34.7	-	-	-	-	SM
7.50-10.00	42	**SS**	Silty Sand	8	-	-	-	-	2.7	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM
10.00-12.00	65	**SS**	Silty Sand	6	-	-	-	-	2.7	-	20	-	-	V.Dense	0	0	0	71	29	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-110

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	10.50	7.79	145.32	100.34

IR KM 110 (MEERUT - SAHARANPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 1.60m depth below)**

Type of Strata	Filled Up Soil
Colour	-
Thickness of Layer	1.60m
SPT of the layer	-
Relative Density	-
Angle of Shearing Resistance, ϕ	-

* **Layer-2 (from 1.60m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	5.90m
SPT of the layer	27
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.10 Deg.

* **Layer-3 (from 7.50m to 10.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m
SPT of the layer	42
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.20 Deg.

* **Layer-4 (from 10.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	2.50m
SPT of the layer	65

Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.50 Deg.

The ground water table was encountered at a depth of 9.20m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of silty sand

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level i.e. 3.10m below existing ground level (considering 1.60m thick fill). The safe bearing capacity of proposed foundation system at a

recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	22	44

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 110 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of silty sand and good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of silty sand, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level i.e. 3.10m below existing ground level (considering 1.60m thick fill). The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 110 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	3.10	m
Observed Maximum thickness of Filled up Soil:	1.60	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Sand	
Least SPT-value of the Bearing Strata :	22	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.60	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

$N_c =$ N/A

$N_q =$ 29.13

$N_\gamma =$ 40.85

Shape Factors:

$S_c =$ N/A

$S_q =$ 1.30

$S_\gamma =$ 1.00

Depth Factors :

$D_c =$ N/A

$D_q =$ 1.00

$D_\gamma =$ 1.00

Inclination Factor:

$I_c =$ N/A

$I_q =$ 1.00

$I_\gamma =$ 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C + q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 571.23 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	228.49	kPa
Limited to an allowable bearing pressure per running meter width:	220.00	kPa

2 Settlements

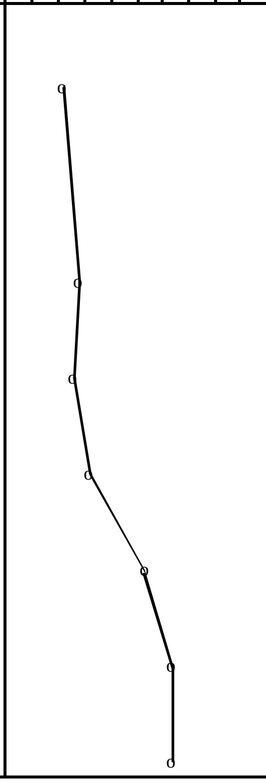
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 22 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 112 (MEERUT - SAHARANPUR SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 14/06/2008; Ended On : 14/06/2008 G.W.T: 9.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
									## 10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
1.50			Greyish to Brownish Loose Silty Fine Sand	1.50	8	10	12	22		M.Dense	SS
				3.00	UDS Collected					M.Dense	SS
			Brownish Medium Dense Sandy Clayey Silt	4.50	10	13	15	28		M.Dense	SS
				6.00	11	12	14	26		M.Dense	SS
7.50				7.50	15	19	23	42		Dense	SS
9.00			Greyish Dense Silty Fine Sand	9.00	18	24	29	53		V.Dense	SS
G.W.T			Greyish Very Dense Silty Fine Sand	10.50	26	30	34	64		V.Dense	SS
12.00				12.00	21	29	35	64		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM- 112 Location

IR KM 112 (MEERUT - SAHARANPUR SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 112 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay: LL (%)	Clay: PL (%)	Clay: PI	Clay: Consistency, I_C	Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis: Gravel (%)	Sieve Analysis: Coarse (%)	Sieve Analysis: Medium (%)	Sieve Analysis: Fine (%)	Sieve Analysis: Silt (%)	Sieve Analysis: Clay (%)	Triaxial Test: c (kN/m^2)	Triaxial Test: ϕ (Deg.)	Box Shear: c (kN/m^2)	Box Shear: ϕ (Deg.)	Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
E.G.L-1.50	-	SS	Silty Sand	14	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	91	9	0	-	-	-	-	-	-	SM
1.50-7.50	25	SS	Sandy Clayey Silt	10	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	23	65	12	13.2	33.7	-	-	-	-	SM
7.50-9.00	42	SS	Silty Sand	8	-	-	-	-	2.66	-	19	-	-	Dense	0	0	0	77	23	0	-	-	-	-	-	-	SM
9.00-12.00	59	SS	Silty Sand	6	-	-	-	-	2.65	-	20	-	-	V.Dense	0	0	0	72	28	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 112

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	12.00	7.78	155.32	143.22

IR KM 112 (MEERUT - SAHARANPUR SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

*** Layer-1 (from E.G.L to 1.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish to Brownish
Thickness of Layer	1.50m
SPT of the layer	-
Relative Density	Loose
Angle of Shearing Resistance, ϕ	-

*** Layer-2 (from 1.50m to 7.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Brownish
Thickness of Layer	6.00m
SPT of the layer	25
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.50 Deg.

*** Layer-3 (from 7.50m to 9.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	1.50m
SPT of the layer	42
Relative Density	Dense
Angle of Shearing Resistance, ϕ	39.20 Deg.

*** Layer-4 (from 9.00m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m

SPT of the layer	59
Relative Density	Very Dense
Angle of Shearing Resistance, ϕ	42.35 Deg.

The ground water table was encountered at a depth of 9.50m within the explored depth of investigation in the second week of June 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of non-plastic sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of non-plastic sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of non-plastic sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	22	44

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 112 (MEERUT - SAHARANPUR SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 112 (MEERUT - SAHARANPUR SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Silt	
Least SPT-value of the Bearing Strata :	22	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	33.60	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

$N_c =$ N/A

$N_q =$ 29.13

$N_\gamma =$ 40.85

Shape Factors:

$S_c =$ N/A

$S_q =$ 1.30

$S_\gamma =$ 1.00

Depth Factors :

$D_c =$ N/A

$D_q =$ 1.00

$D_\gamma =$ 1.00

Inclination Factor:

$I_c =$ N/A

$I_q =$ 1.00

$I_\gamma =$ 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 571.23 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	228.49	kPa
Limited to an allowable bearing pressure per running meter width:	220.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 220kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 220kPa and SPT of 22 are computed to be in the order of 44mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

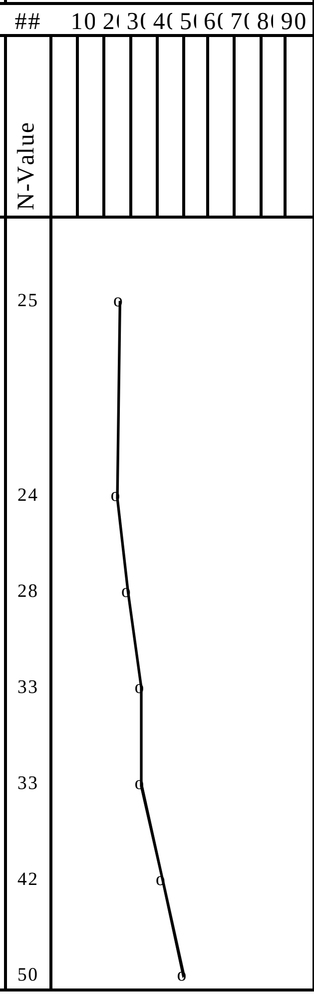
TALHERI – PILKHANI SECTION

IR KM 155 (TALHERI - PILKHANI SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 07/07/2008; Ended On : 07/07/2008 G.W.T: 5.50m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	SPT - Details 0-15 cm	15-30 cm	30-45 cm	N-Value	raphical Representation of SP	Relative Density/Consistency	Type of Sample
			Greyish to Brownish Medium Dense Sandy Clayey Silt	1.50	8	12	13	25		M.Dense	SS
				3.00	UDS Collected					M.Dense	SS
				4.50	10	12	12	24		M.Dense	SS
5.50			Brownish Medium Dense Silty Fine Sand	6.00	8	11	17	28		M.Dense	SS
7.50				7.50	12	16	17	33		Dense	SS
			Greyish Dense Silty Fine Sand	9.00	13	15	18	33		Dense	SS
				10.50	18	20	22	42		Dense	SS
12.00				12.00	20	25	25	50		Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-155 Location

IR KM 155 (TALHERI - PILKHANI SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM. 155 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-5.50	24	SS	Sandy Clayey Silt	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	21	55	24	14.5	33.6	-	-	-	-	SM
5.50-7.50	28	SS	Silty Sand	10	-	-	-	-	2.66	-	17	-	-	M.Dense	0	0	0	81	19	0	-	-	-	-	-	-	SM
7.50-12.00	36	SS	Silty Sand	8	-	-	-	-	2.65	-	19	-	-	Dense	0	0	0	78	22	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM. 155

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.82	90.39	95.64

IR KM 155 (TALHERI - PILKHANI SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 5.50m depth below)**

Type of Strata	Sandy Clayey Silt
Colour	Greyish to Brownish
Thickness of Layer	5.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	34.20 Deg.

* **Layer-2 (from 5.50m to 7.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	2.00m
SPT of the layer	28
Relative Density	Medium Dense
Angle of Shearing Resistance, ϕ	35.40 Deg.

* **Layer-3 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	4.50m
SPT of the layer	36
Relative Density	Dense
Angle of Shearing Resistance, ϕ	37.65 Deg.

The ground water table was encountered at a depth of 5.50m within the explored depth of investigation in the first week of July 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.

As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the bearing strata of the proposed foundation system can be the sub soil strata encountered at shallow depths in the form of sandy clayey silt.

Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural

ground level. The safe bearing capacity of proposed foundation system at a recommended depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Type of Foundation Structure	Recommended Minimum Depth of Footing below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	Isolated Column Footing/Raft	1.50	25	40

Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904. The details of the computations are annexed to this report.

IR KM 155 (TALHERI - PILKHANI SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. immediately as top sub-surface strata are coarse-grained type in the form of sandy clayey silt and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. As the sub-surface strata encountered at the investigation locations at shallow depths are coarse-grained type met in the form of sandy clayey silt, the safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure of the overlying soil on the bearing strata.
3. Considering the shear strength characteristics of sub-soil strata encountered at the investigation location, the foundation system can be isolated footing type/raft located at a depth of 1.50m below the natural ground level. The safe bearing capacity of proposed foundation systems at a recommended depth of 1.50m below the natural ground level as presented in Clause 4.2.1, Chapter-IV can be adopted for foundation design purposes.
4. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 50mm for individual footings and 70mm for rafts as per revised I.S: 1904.
5. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
6. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
7. As the sub-soil strata encountered at shallow depths possess good consistency or bulk density in their natural states, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 155 (TALHERI - PILKHANI SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Sandy Clayey Silt	
Least SPT-value of the Bearing Strata :	25	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	34.50	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	17.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.50	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 31.81

N_γ = 45.47

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	627.44	kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) :	2.50	
Qsafe :	250.98	kPa
Limited to an allowable bearing pressure per running meter width:	250.00	kPa

2 Settlements

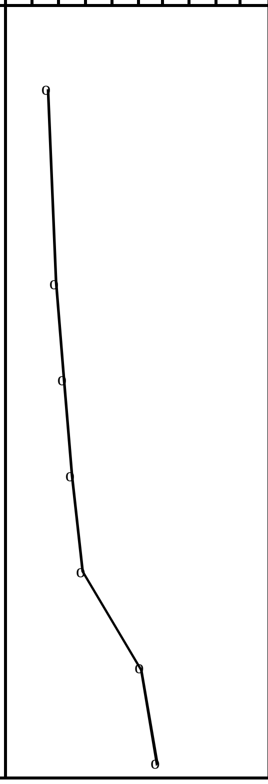
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 250kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 250kPa and SPT of 25 are computed to be in the order of 40mm which is within the permissible limits of 50mm for individual column footings as per I.S:1904.

IR KM 156 (TALHERI - PILKHANI SECTION)

Project : Proposed Dedicated Freight Corridor from Kulwa to Khurja, Khurja to Dadri and Khurja to Talheri at Km156 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Started On : 07/07/2008; Ended On : 07/07/2008 G.W.T: 5.00m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	Depth of SPT (m)	SPT - Details 0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 20 30 40 50 60 70 80 90)	Relative Density/Consistency	Type of Sample
			Greyish to Brownish Stiff Silty Sandy Clay	1.50	6	7	8	15		Stiff	SS
				3.00	UDS Collected					Stiff	SS
4.00											
G.W.T			Brownish Medium Dense Silty Fine Sand	4.50	5	8	10	18		M.Dense	SS
				6.00	8	10	11	21		M.Dense	SS
				7.50	10	10	15	25		M.Dense	SS
				9.00	11	14	15	29		M.Dense	SS
10.50				10.50	18	23	28	51		V.Dense	SS
12.00			Greyish Very Dense Silty Fine Sand	12.00	20	26	31	57		V.Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at KM-156 Location

IR KM 156 (TALHERI - PILKHANI SECTION)

Table 2.1: Laboratory Test Results on the Soil Samples Collected from KM-156 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-4.00	15	**SS, UDS**	Silty Clay	33	78	31	47	1	2.67	0.88	17	65	60	Stiff	0	0	0	0	24	76	96.9	14.3	-	-	100.0	0.61	CH
4.00-10.50	23	SS	Silty Sand	8	-	-	-	-	2.66	0.21	18	-	-	Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM
10.50-12.00	51	SS	Silty Sand	6	-	-	-	-	2.65	0.16	20	-	-	V.Dense	0	0	0	73	27	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at KM-156

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	6.00	7.86	100.17	99.64

IR KM 156 (TALHERI - PILKHANI SECTION)

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at KM- 156 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 4.00m depth below)**

Type of Strata	Silty Sandy Clay
Colour	Brownish
Thickness of Layer	4.00m
SPT of the layer	15
Consistency	Stiff
Undrained Cohesion, Cu	100.00kPa

* **Layer-2 (from 4.00m to 10.50m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	6.50m
SPT of the layer	23
Relative Density	Medium Dense
Angle of Shearing Resistance	33.90^{o}

* **Layer-3 (from 10.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Greyish
Thickness of Layer	3.00m
SPT of the layer	51
Relative Density	Very Dense
Angle of Shearing Resistance	41.15^{o}

The ground water table was encountered at a depth of 5.00m within the explored depth of investigation in the first week of July 2008.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System without Ground Improvement Technique

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as fine-grained soil strata can be considered as bearing strata if the foundation system is located below the zone of desiccation i.e. 2.50m below the natural ground level.

The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L). Hence, the foundation system can be raft located at a depth of 2.50m below the existing ground level (E.G.L). The safe bearing capacity of the foundation system will be independent of

width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.

The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L (m)	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)
1	2.50	21	66

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

IR KM 156 (TALHERI - PILKHANI SECTION)

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths i.e. **immediately below the filled up soil strata are fine-grained type in the form of highly plastic silty clay which can undergo volumetric change phenomenon with the variations in seasonal moisture content and can be considered as bearing strata from both shear and deformation considerations for the proposed impending loads from the superstructure provided that the foundation system is located below the zone of desiccation.**
2. The foundation system shall be located at a depth of 2.50m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be independent of width of the footing and effective overburden pressure over the bearing strata and will be a function of unconfined compressive strength of it.
4. **The safe bearing capacity of raft located at a depth of 2.50m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the sub-soil strata encountered at shallow depths possess good consistency, no provision of bracing to contain any lateral collapse of soil in the foundation pits is required.

9. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

IR KM 156 (TALHERI - PILKHANI SECTION)

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clay	
Least SPT-value of the Bearing Strata :	15	
Type of Shear Failure:	General	
Undrained Cohesion, Cu:	100.00	kPa

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	15.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = 5.14

N_q = N/A

N_γ = N/A

Shape Factors:

S_c = 1.30

S_q = N/A

S_γ = N/A

Depth Factors :

D_c = 1.00

D_q = N/A

D_γ = N/A

Inclination Factor:

I_c = 1.00

I_q = N/A

I_γ = N/A

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 668.20 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 267.28 kPa

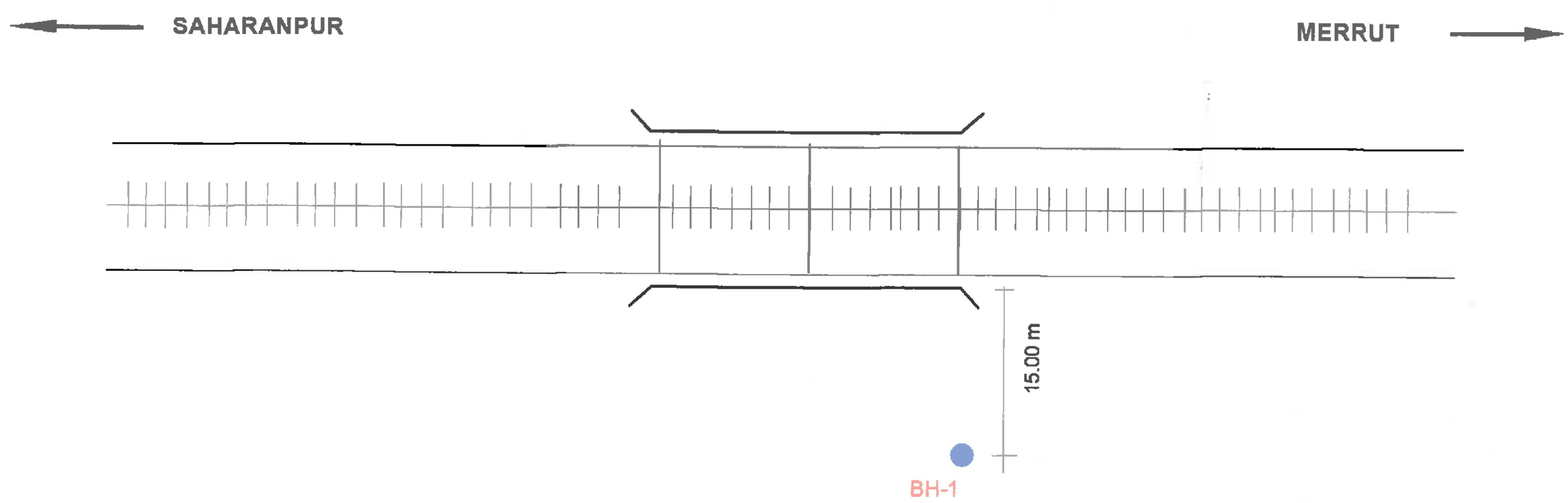
Limited to an allowable bearing pressure per running meter width: 210.00 kPa

2 Settlements

Since, the bearing strata are fine-grained type, the settlements under the allowable safe bearing pressure of 210kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 210kPa and SPT of 15 are computed to be in the order of 66mm which is within the permissible limits of 70mm for rafts as per I.S:1904.

SOIL ENGINEERING CONSULTANTS

Job No: 1813



BRIDGE 203 @ 156/3-4

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiana to Saharanpur

Fig: Plan- A

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

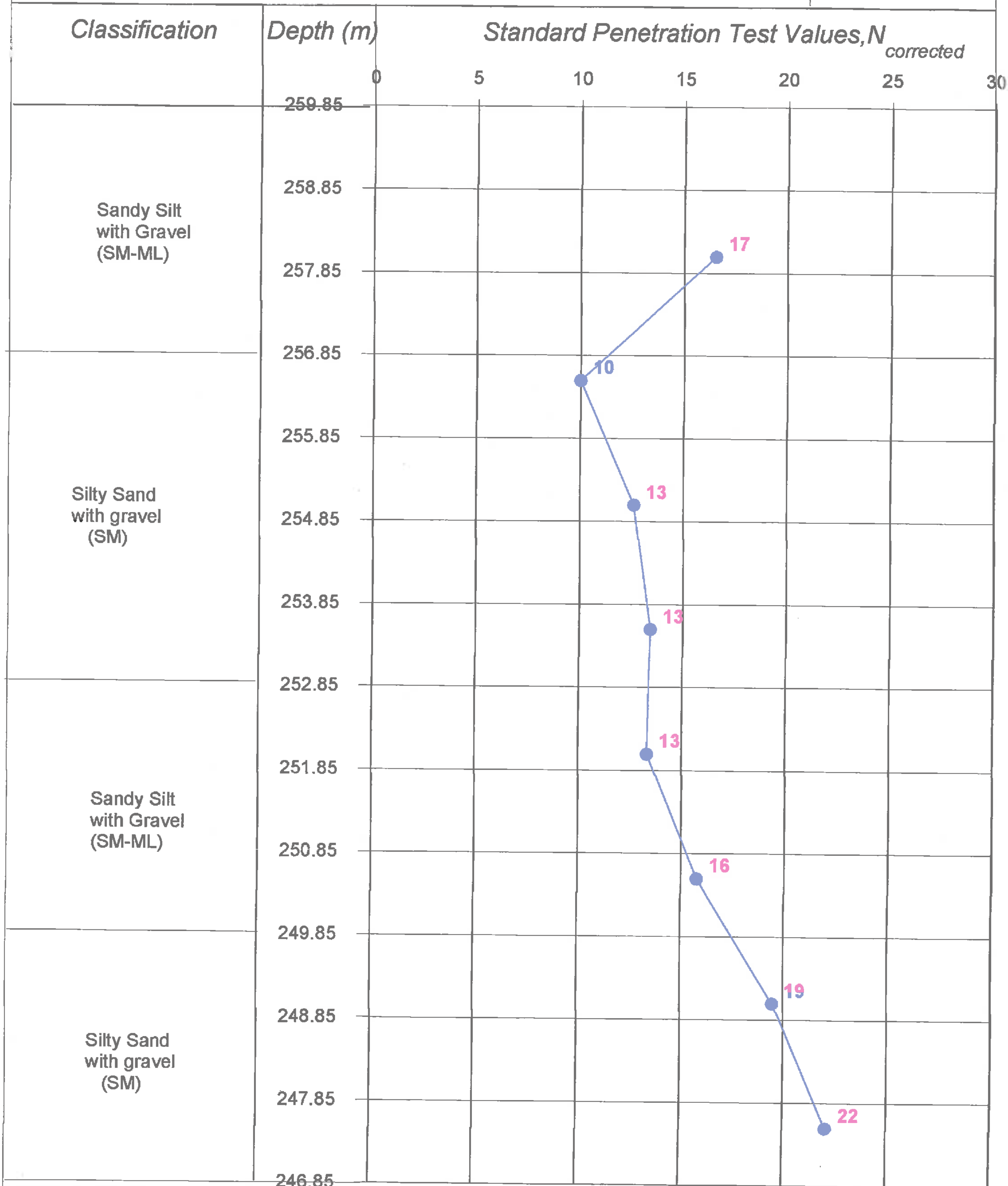
Project No. 1813 Bridge : 203 RL: 259.850

Location; 156/3-4
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 15/07/2008
Date of finish : 15/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P. L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
259.850																	
259.350	0.50	DS	Sandy Silt with Gravel (SM-ML)								Non	Plastic					
258.050	1.80	SPT		12	0	2	98				Non	Plastic					
257.350	2.50	UDS	Silty Clay of medium plasticity (CI)					1.75	1.56	11.92			2.69	UU	0.53	6	0.071
256.550	3.30	SPT		10	0	2	98				46	22					
255.050	4.80	SPT	Sandy Silt with Gravel (SM-ML)	12	0	2	98				Non	Plastic					
254.350	5.50	UDS						1.76	1.54	14.13			2.65	DST	0.15	30	
253.550	6.30	SPT		14	2	6	92				Non	Plastic					
252.050	7.80	SPT		15	0	1	99				Non	Plastic					
250.550	9.30	SPT		19	0	2	98				Non	Plastic					
249.050	10.80	SPT		25	0	6	94				Non	Plastic					
247.550	12.30	SPT		30	0	4	96				Non	Plastic					

SOIL ENGINEERING CONSULTANTS Br :203/156/3-4 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-A

SOIL ENGINEERING CONSULTANTS

Job No: 1813

Interdistance @ 157/3-4

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-B

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Interdistance RL: 259.950

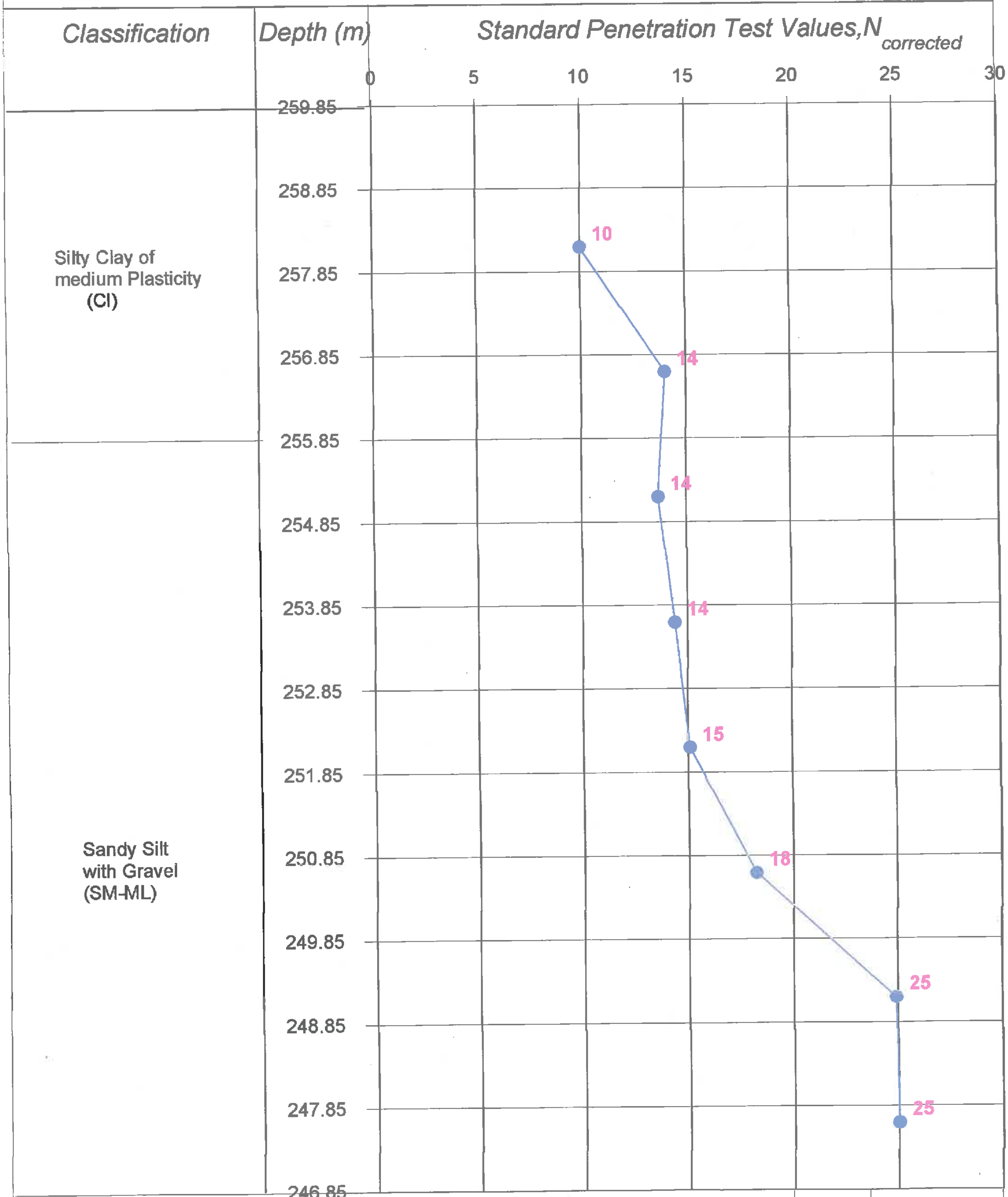
Location; 157/3-4
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 16/07/2008
Date of finish : 17/07/2008

SOIL ENGINEERING CONSULTANTS

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P. L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
259.950																	
258.150	1.80	SPT	Silty Clay of medium Plasticity (CI)	10	6	12	82				38	19					
257.450	2.50	UDS						1.78	1.56	14.46			2.69	UU	0.52	6	
256.650	3.30	SPT		14	0	2	98				39	22					
255.150	4.80	SPT	Sandy Silt with Gravel (SM-ML)	13	1	7	92				Non	Plastic					
254.450	5.50	UDS						1.8	1.56	15.41			2.65	DST	0.1	30	
253.650	6.30	SPT		15	0	8	92				Non	Plastic					
252.150	7.80	SPT		17	0	26	74				Non	Plastic					
251.450	8.50	UDS						1.82	1.57	15.69			2.65	DST	0.1	30	
250.650	9.30	SPT		22	0	18	82				Non	Plastic					
249.150	10.80	SPT		32	2	11	87				Non	Plastic					
248.450	11.50	UDS						1.86	1.59	17.24				DST	0.15	31	
247.650	12.30	SPT		34	1	20	79				Non	Plastic					

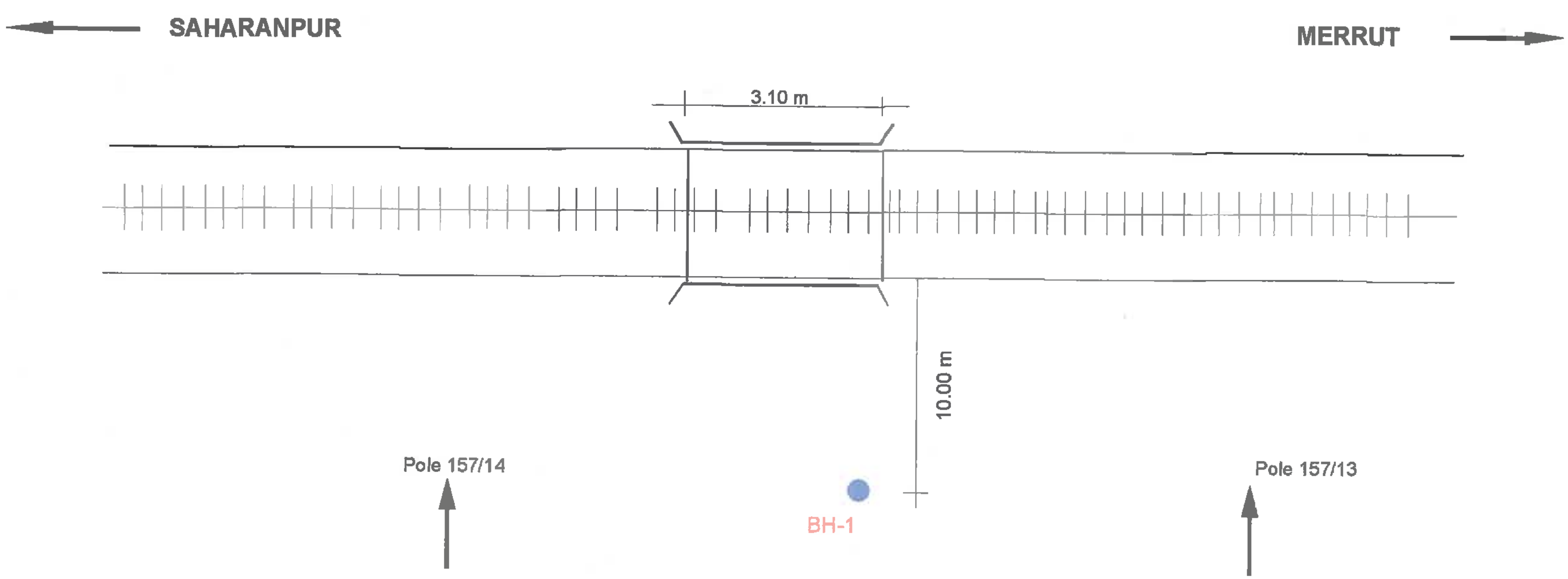
SOIL ENGINEERING CONSULTANTS | Interdistance@ 157/3-4 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-B

SOIL ENGINEERING CONSULTANTS

Job No: 1813



BRIDGE 204 @ 157/13-14

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-C

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

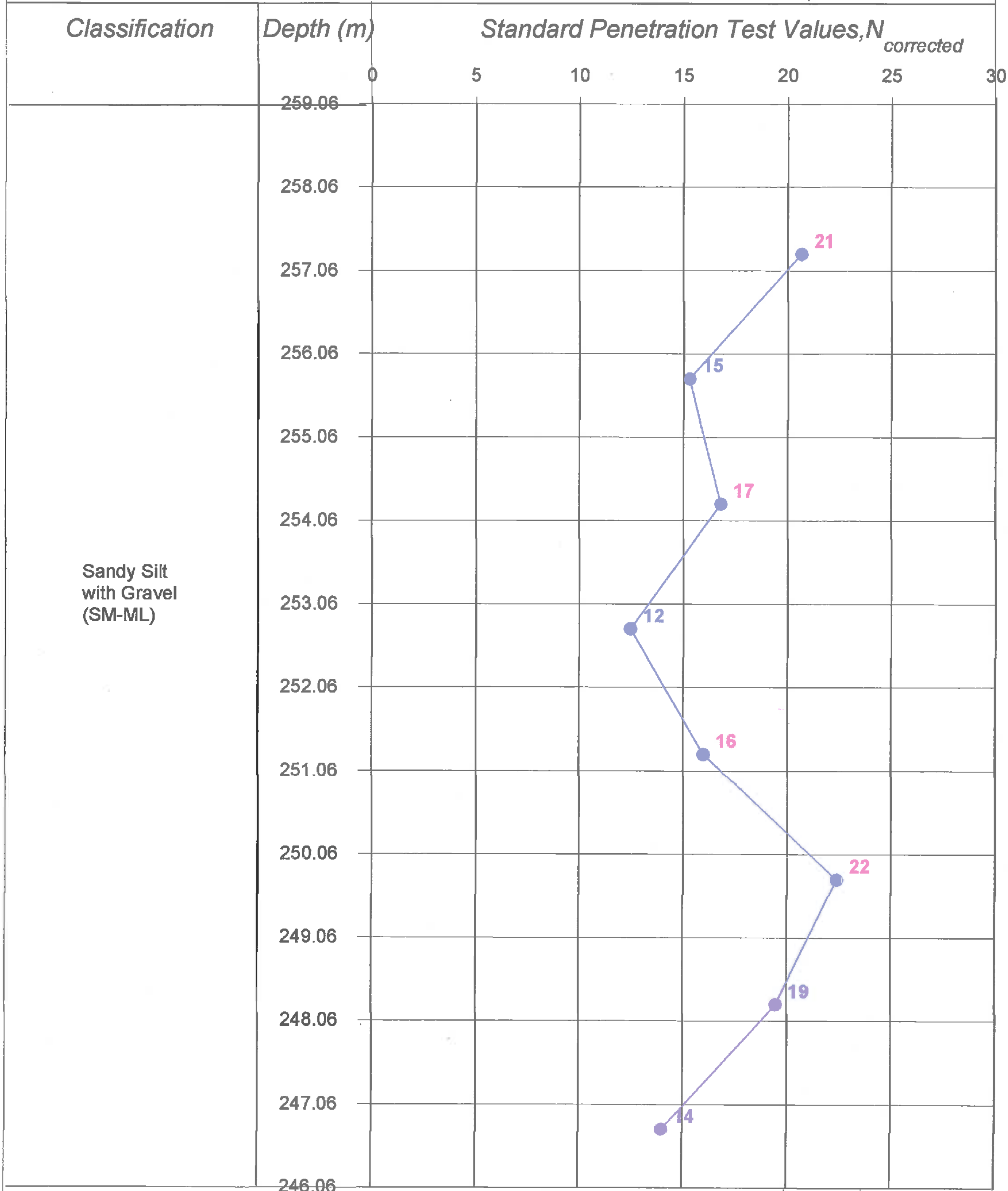
Project No. 1813 Bridge : 204 RL: 259.060

Location; 157/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 17/07/2008
Date of finish : 18/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P. L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
259.060																	
257.260	1.80	SPT		15	0	19	81				Non	Plastic					
256.560	2.50	UDS						1.78	1.59	11.79				DST	0.1	30	
255.760	3.30	SPT		13	0	41	59				Non	Plastic					
254.260	4.80	SPT		16	0	33	67				Non	Plastic					
253.560	5.50	UDS						1.78	1.58	12.32			2.66	DST	0.12	31	
252.760	6.30	SPT	Sandy Silt with Gravel (SM-ML)	13	0	25	75				Non	Plastic					
251.260	7.80	SPT		18	1	10	89				Non	Plastic					
250.560	8.50	UDS						1.83	1.62	12.96				DST	0.11	31	
249.760	9.30	SPT		27	2	8	90				Non	Plastic					
248.260	10.80	SPT		25	1	10	89				Non	Plastic					
247.560	11.50	UDS						1.85	1.63	13.42			2.67	DST	0.15	31	
246.760	12.30	SPT		19	0	27	73				Non	Plastic					

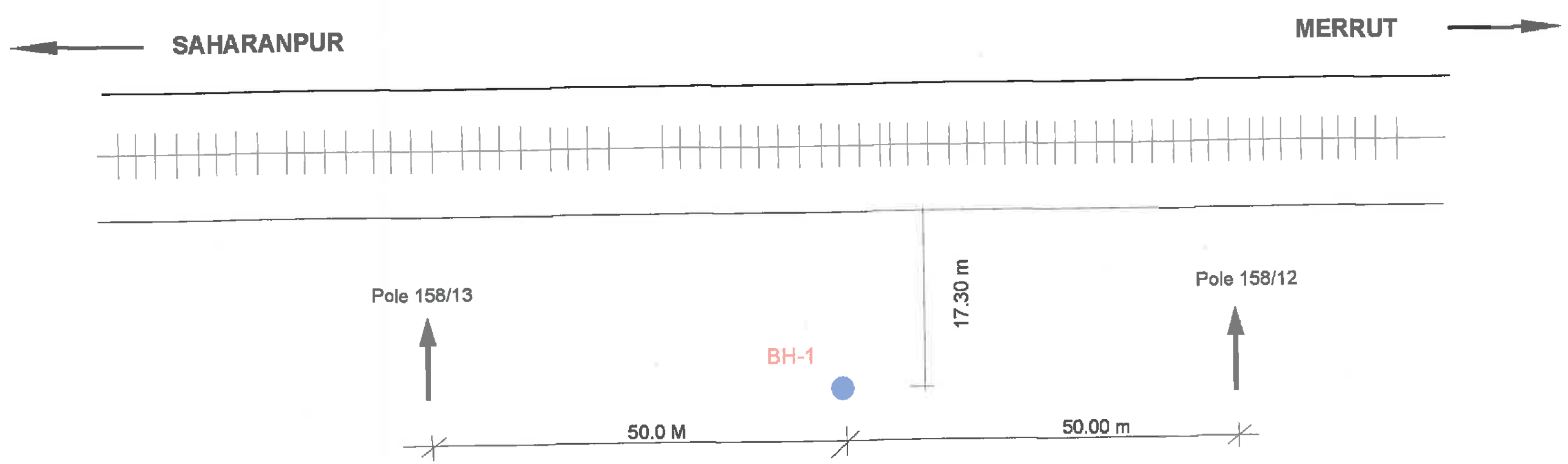
SOIL ENGINEERING CONSULTANTS | Br : 204 @ 157/13-14 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-C

SOIL ENGINEERING CONSULTANTS

Job No: 1813



Interdistance @ 158/12-13

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-D

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

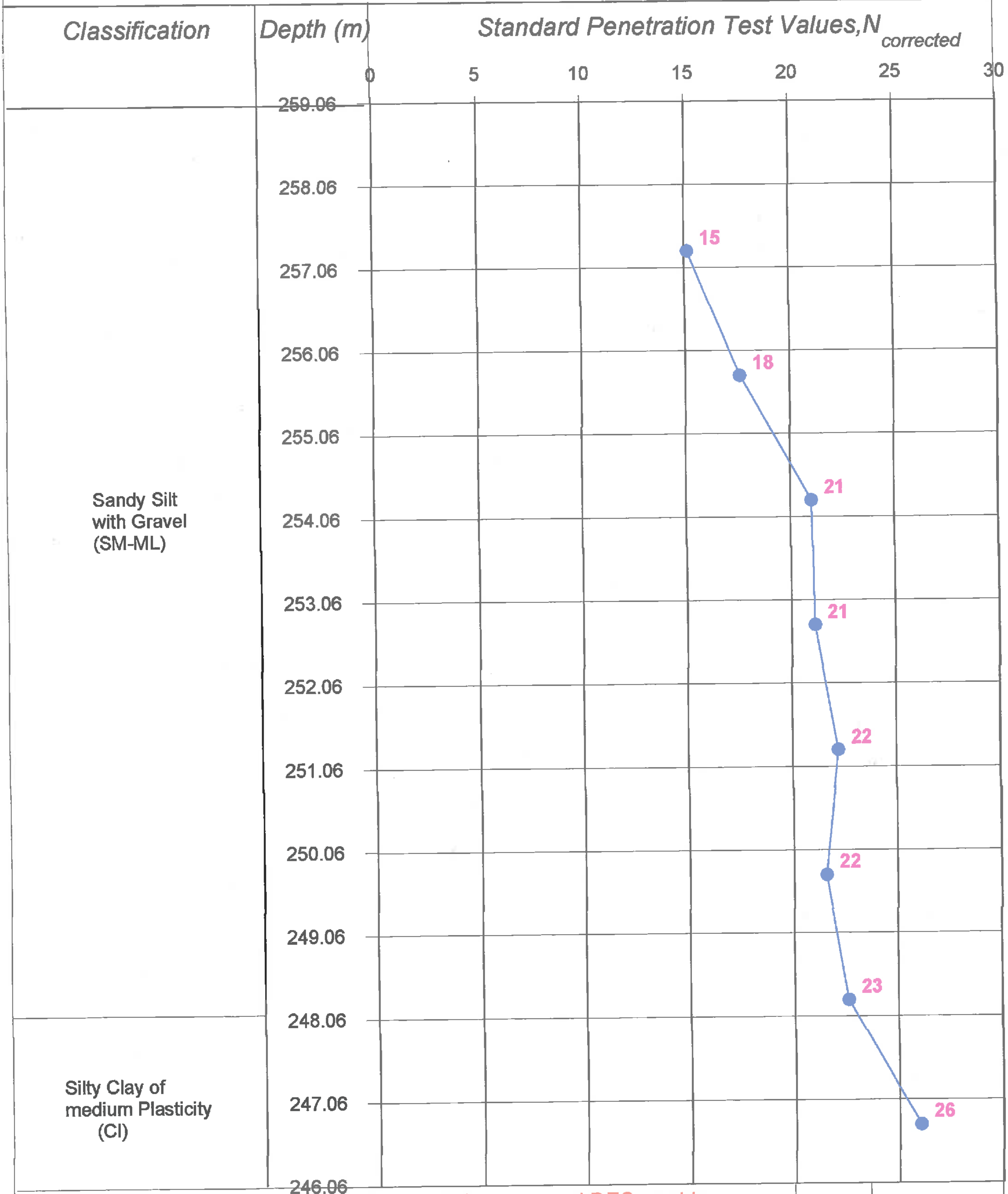
Project No. 1813 Interdistance RL: 259.060

Location; 168/12-13
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 19/07/2008
Date of finish : 19/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P. L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
259.060																	
257.260	1.80	SPT	Sandy Silt with Gravel (SM-ML)	11	3	6	91				Non Plastic						
256.560	2.50	UDS						1.78	1.59	11.92				DST	0.1	30	
255.760	3.30	SPT		15	0	22	78				Non Plastic						
254.260	4.80	SPT		20	0	9	91				Non Plastic						
253.560	5.50	UDS						1.83	1.63	11.96			2.65	DST	0.1	32	
252.760	6.30	SPT		22	0	31	69				Non Plastic						
251.260	7.80	SPT		25	1	26	73				Non Plastic						
250.560	8.50	UDS						1.86	1.64	13.42				DST	0.1	32	
249.760	9.30	SPT		26	0	46	54				Non Plastic						
248.260	10.80	SPT		29	0	15	85				Non Plastic						
246.760	12.30	SPT	Silty Clay of medium Palsticity (CI)	26	0	2	98				39	21					

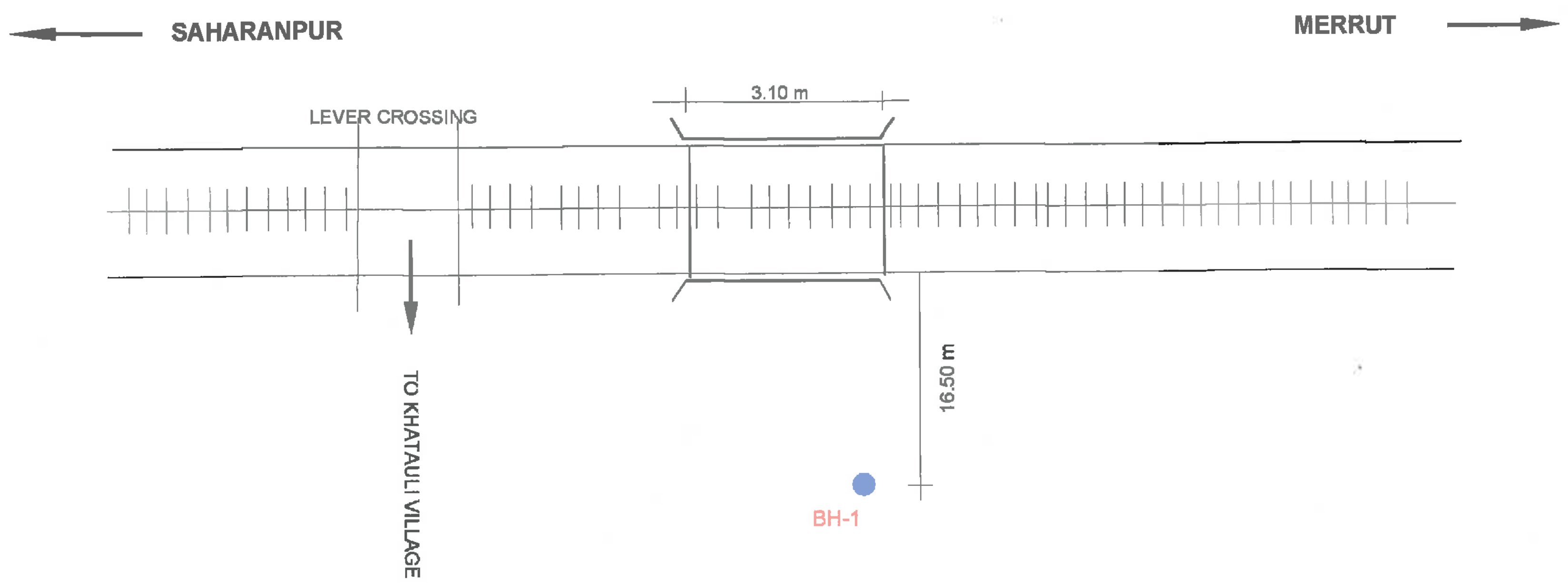
SOIL ENGINEERING CONSULTANTS | Interdistance@ 158/12-13 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-D

SOIL ENGINEERING CONSULTANTS

Job No: 1813



BRIDGE 205 @ 159/01

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-E

BORE LOG

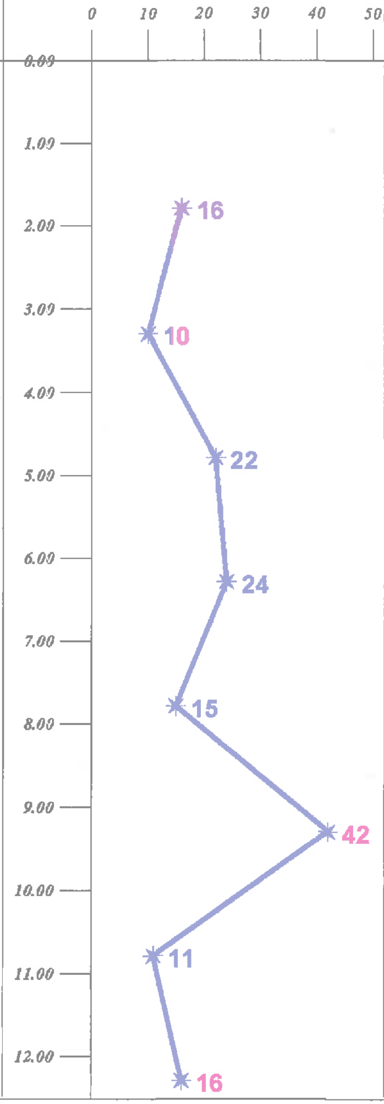
PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Bridge : 205 RL: 261.598

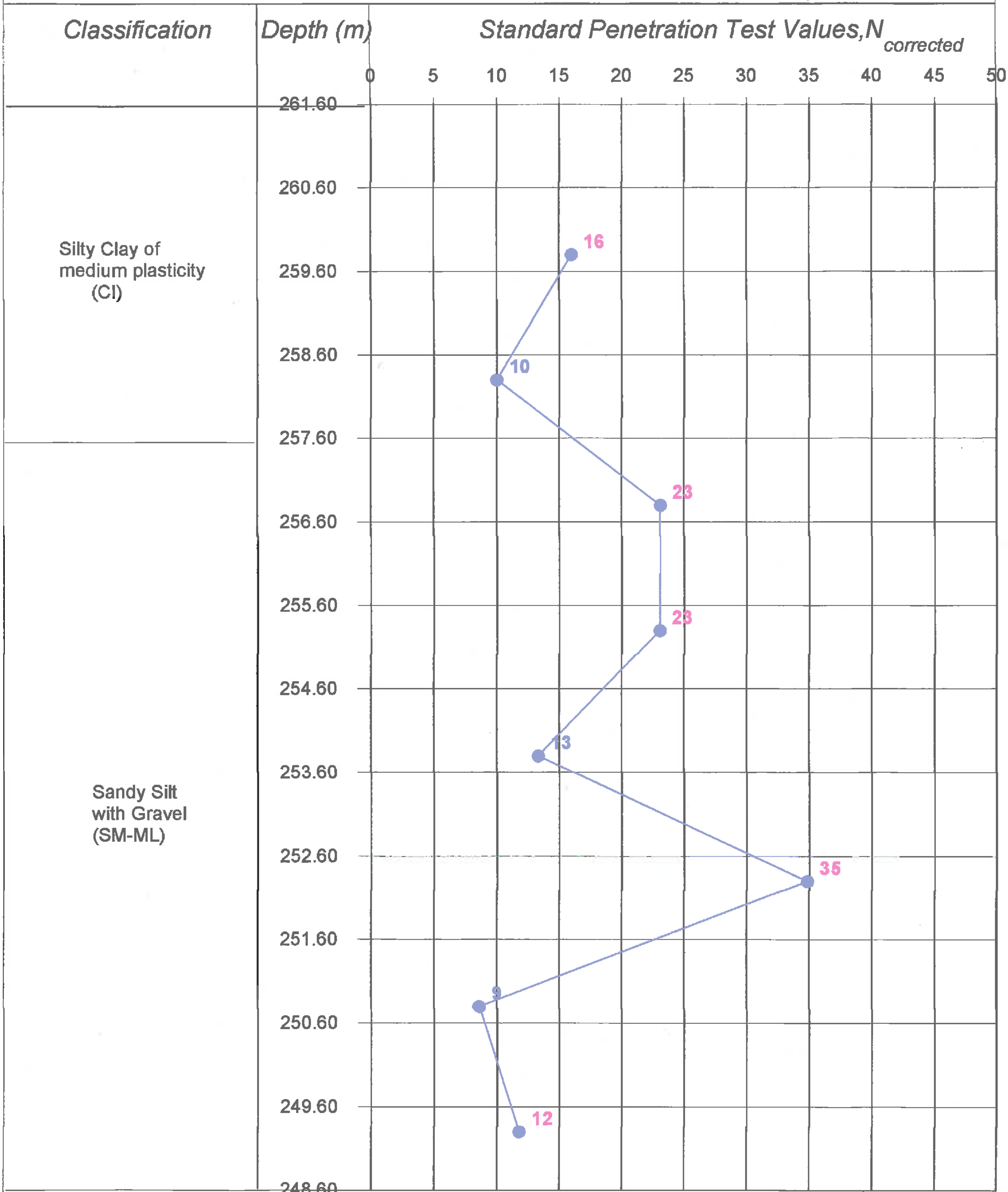
Location;159/01
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 20/07/2008
Date of finish : 20/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P. L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
261.598																	
259.798	1.80	SPT	Silty Clay of medium Plasticity (CI)	16	3	19	78				44	26					
259.098	2.50	UDS						1.8	1.61	11.93				UU	0.56	6	0.077
258.298	3.30	SPT		10	3	3	94				42	24					
256.798	4.80	SPT	Sandy Silt with Gravel (SM-ML)	22	0	2	98				Non	Plastic					
256.098	5.50	UDS						1.89	1.65	14.42			2.65	DST	0.15	32	
255.298	6.30	SPT		24	0	19	81				Non	Plastic					
253.798	7.80	SPT		15	0	22	78				Non	Plastic					
253.098	8.50	UDS						1.88	1.63	15.51				DST	0.15	31	
252.298	9.30	SPT		42	1	10	89				Non	Plastic					
250.798	10.80	SPT		11	0	1	99				Non	Plastic					
249.298	12.30	SPT		16	0	4	96				Non	Plastic					



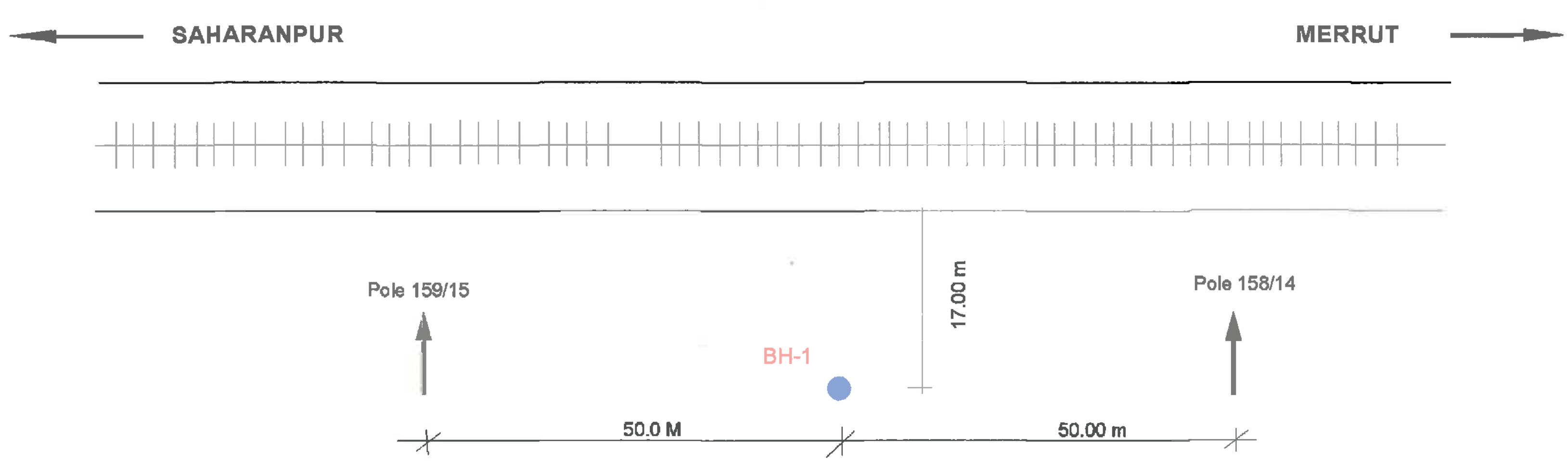
SOIL ENGINEERING CONSULTANTS	Br : 205 @ 159/01	Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur	BH-1	Fig: SP-E

SOIL ENGINEERING CONSULTANTS

Job No: 1813



Interdistance @ 159/14-15

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-F

BORE LOG

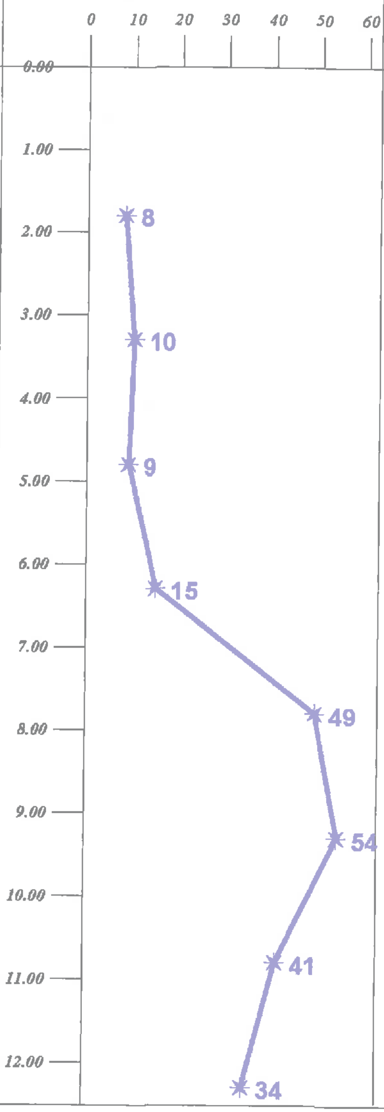
PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Interdistance RL: 261.726

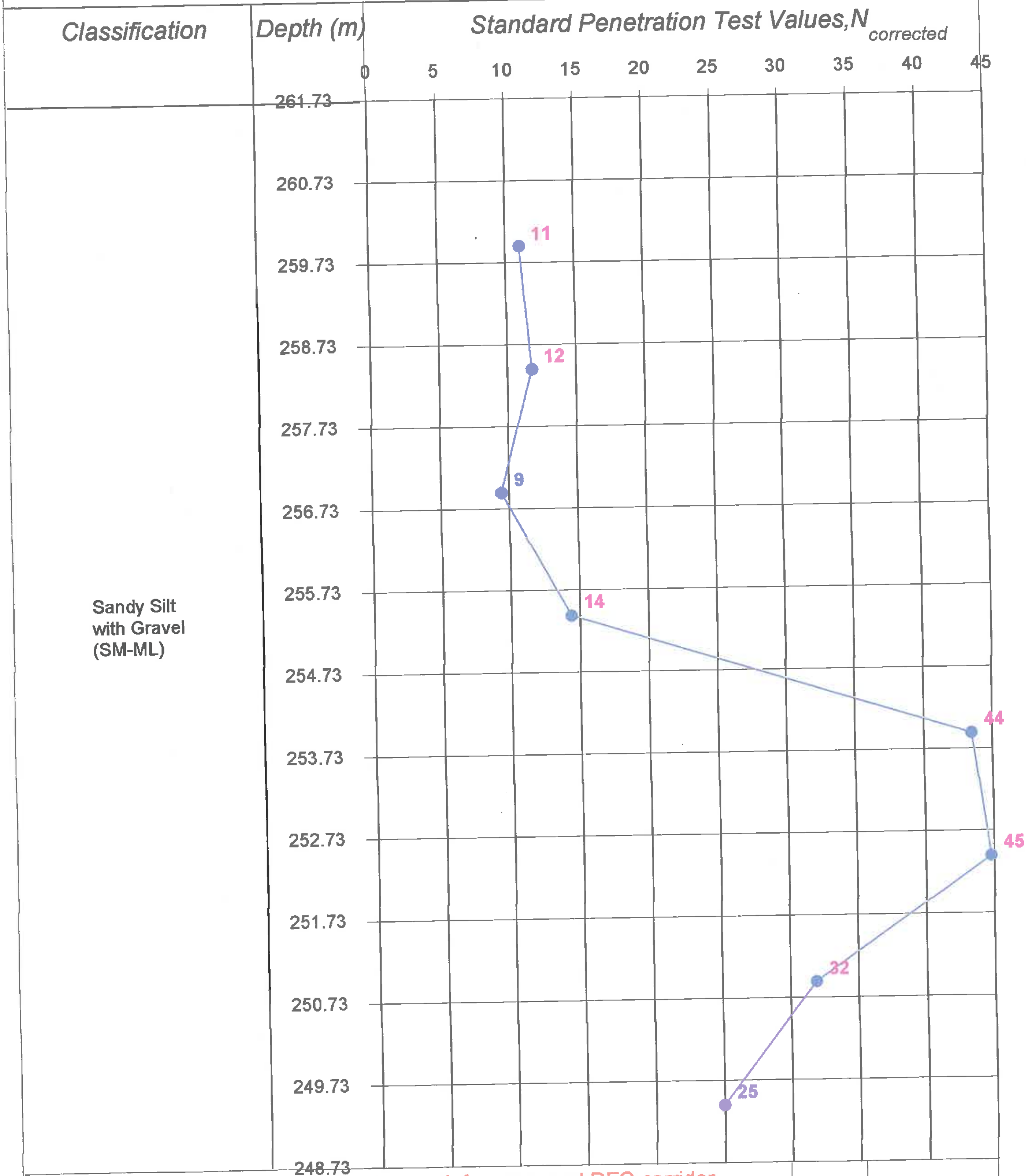
Location; 159/14-15
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 21/07/2008
Date of finish : 22/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P.L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
261.726																	
259.926	1.80	SPT		8	0	2	98				Non	Plastic					
259.226	2.50	UDS						1.79	1.59	12.69			2.65	DST	0.1	29	
258.426	3.30	SPT		10	0	1	99				Non	Plastic					
256.926	4.80	SPT		9	17	2	81				Non	Plastic					
256.226	5.50	UDS	Sandy Silt with Gravel (SM-ML)					1.79	1.56	14.45				DST	0.1	29	
255.426	6.30	SPT		15	1	6	93				Non	Plastic					
253.926	7.80	SPT		49	0	10	90				Non	Plastic					
252.426	9.30	SPT		54	2	13	85				Non	Plastic					
250.926	10.80	SPT		41	1	28	71				Non	Plastic					
249.426	12.30	SPT		34	0	21	79				Non	Plastic					



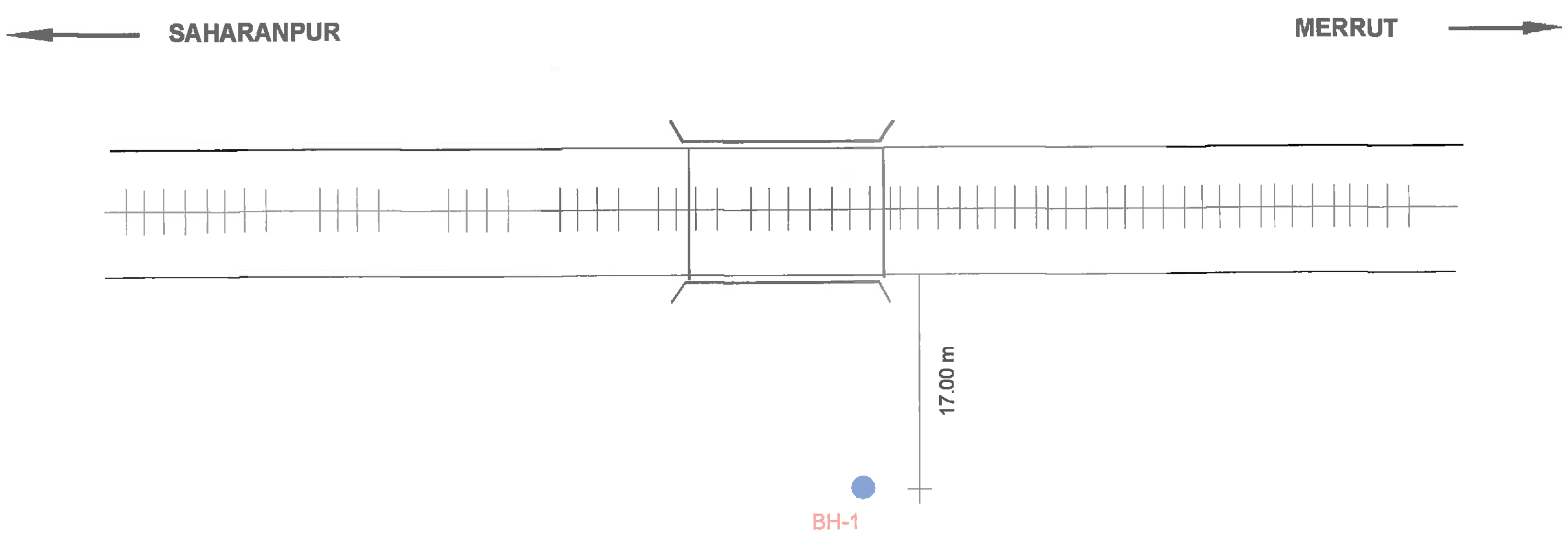
SOIL ENGINEERING CONSULTANTS | Interdistance@ 159/14-15 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-1

SOIL ENGINEERING CONSULTANTS

Job No: 1813



BRIDGE 206 @ 160/13-14

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-G

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Bridge : 206 RL: 259.869

Location;160/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

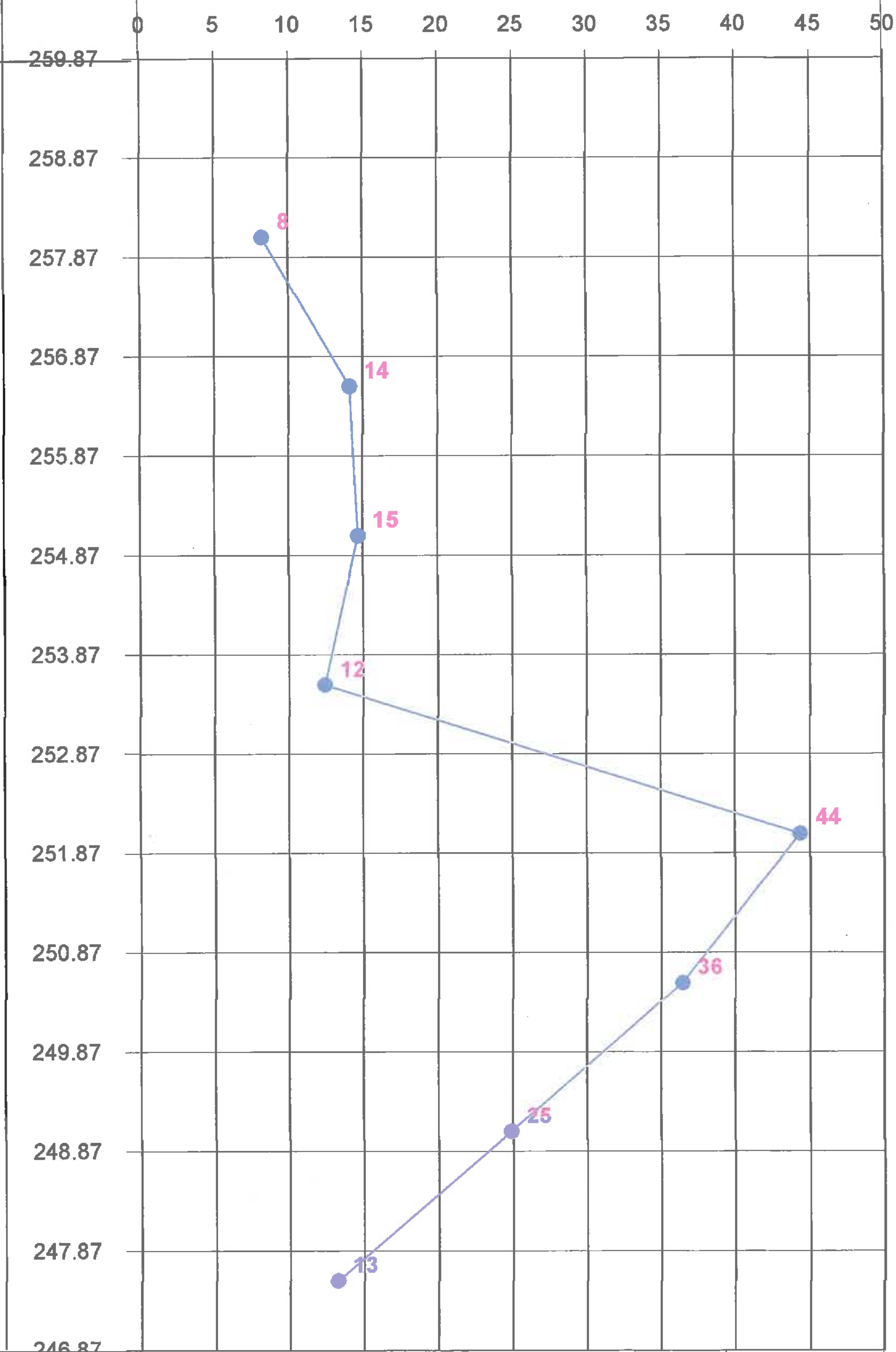
Date of start : 23/07/2008
Date of finish : 23/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P.L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
259.869																	
258.069	1.80	SPT		6	2	4	94				Non	Plastic					
257.369	2.50	UDS						1.84	1.64	12.34			2.65	DST	0.15	29	
256.569	3.30	SPT		12	3	7	90				Non	Plastic					
255.069	4.80	SPT		14	0	2	98				Non	Plastic					
254.369	5.50	UDS	Sandy Silt with Gravel (SM-ML)					1.86	1.63	14.41				DST	0.15	30	
253.569	6.30	SPT		13	0	1	99				Non	Plastic					
252.069	7.80	SPT		50	0	11	89				Non	Plastic					
250.569	9.30	SPT		44	0	13	87				Non	Plastic					
249.069	10.80	SPT		32	0	6	94				Non	Plastic					
247.569	12.30	SPT		18	3	3	94				Non	Plastic					

SOIL ENGINEERING CONSULTANTS Br : 206 @ 160/13-14 Project No: 1813

Classification | *Depth (m)* | *Standard Penetration Test Values, $N_{corrected}$*

Sandy Silt
with Gravel
(SM-ML)



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

BH-1 Fig: SP-G

SOIL ENGINEERING CONSULTANTS

Job No: 1813

Interdistance @ 161/13-14

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-H

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Interdistance RL: 262.330

Location; 161/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

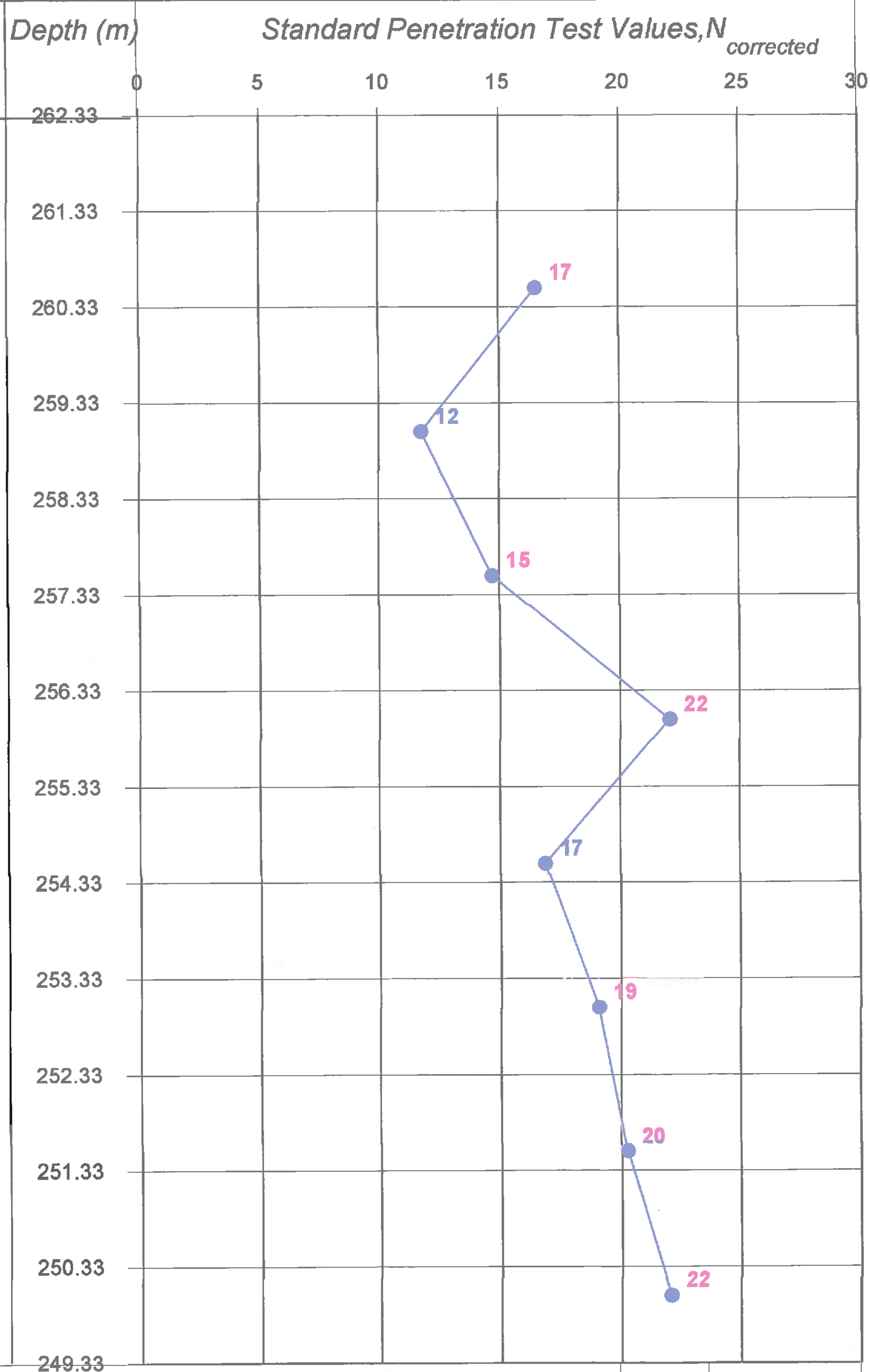
Date of start : 24/07/2008
Date of finish : 24/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P. L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
262.330																	
260.530	1.80	SPT		12	2	4	94				Non	Plastic					
259.830	2.50	UDS						1.79	1.60	11.84				DST	0.1	29	
259.030	3.30	SPT		10	2	6	92				Non	Plastic					
257.530	4.80	SPT		14	0	3	97				Non	Plastic					
256.830	5.50	UDS	Sandy Silt with Gravel (SM-ML)					1.82	1.62	12.43				DST	0.15	30	
256.030	6.30	SPT		23	4	9	87				Non	Plastic					
254.530	7.80	SPT		19	0	12	88				Non	Plastic					
253.830	8.50	UDS						1.86	1.64	13.61				DST	0.18	32	
253.030	9.30	SPT		23	0	3	97				Non	Plastic					
251.530	10.80	SPT		26	0	2	98				Non	Plastic					
250.030	12.30	SPT		30	0	16	84				Non	Plastic					

SOIL ENGINEERING CONSULTANTS | Interdistance@ 161/13-14 | Project No: 1813

Classification

Sandy Silt
with Gravel
(SM-ML)



PROJECT: Geotechnical Investigation work for proposed DFC corridor
from Ludhiyana to Saharanpur

BH-1 | Fig: SP-H

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Bridge : 207 RL : 263.585

Location; 162/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

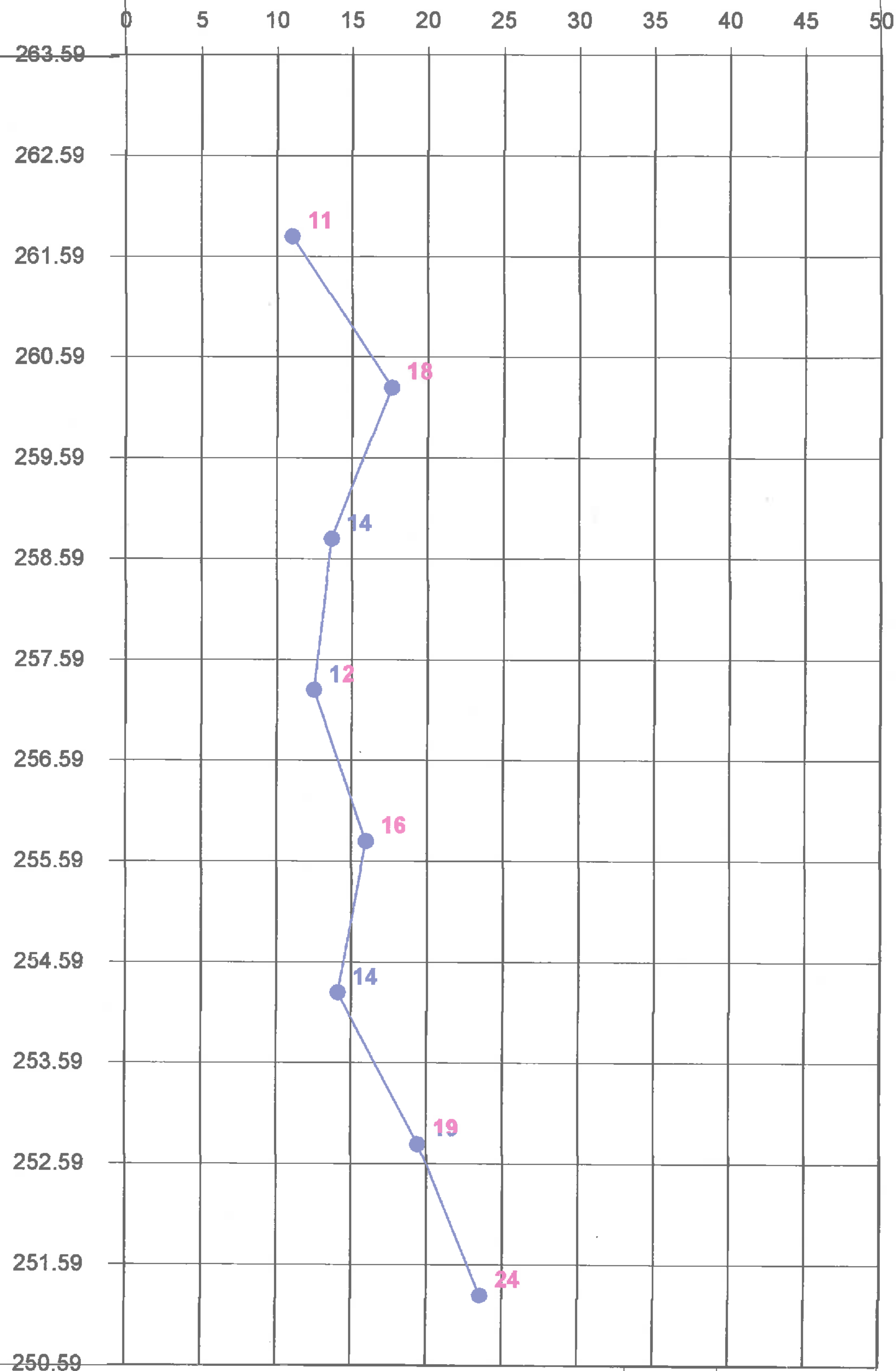
Date of start : 27/07/2008
Date of finish : 27/07/2008

SOIL ENGINEERING CONSULTANTS

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P.L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
263.585																	
261.785	1.80	SPT	Sandy Silt with Gravel (SM-ML)	8	1	4	95				Non	Plastic					
261.085	2.50	UDS						1.76	1.55	13.81				DST	0.15	29	
260.285	3.30	SPT	Silty Sand with gravel (SM)	15	0	53	47				Non	Plastic					
258.785	4.80	SPT		13	0	59	41				Non	Plastic					
258.085	5.50	UDS						1.8	1.57	14.62			2.66	DST	0.1	30	
257.285	6.30	SPT		13	0	78	22				Non	Plastic					
255.785	7.80	SPT	Sandy Silt with Gravel (SM-ML)	18	1	26	73				Non	Plastic					
255.085	8.50	UDS						1.83	1.57	16.86			2.66	DST	0.1	30	
254.285	9.30	SPT		17	0	4	96				Non	Plastic					
252.785	10.80	SPT		25	0	47	53				Non	Plastic					
252.085	11.50	UDS						1.87	1.58	18.20				DST	0.1	31	
251.285	12.30	SPT		32	1	39	60				Non	Plastic					

SOIL ENGINEERING CONSULTANTS	Br : 207 @ 162/13-14	Project No: 1813

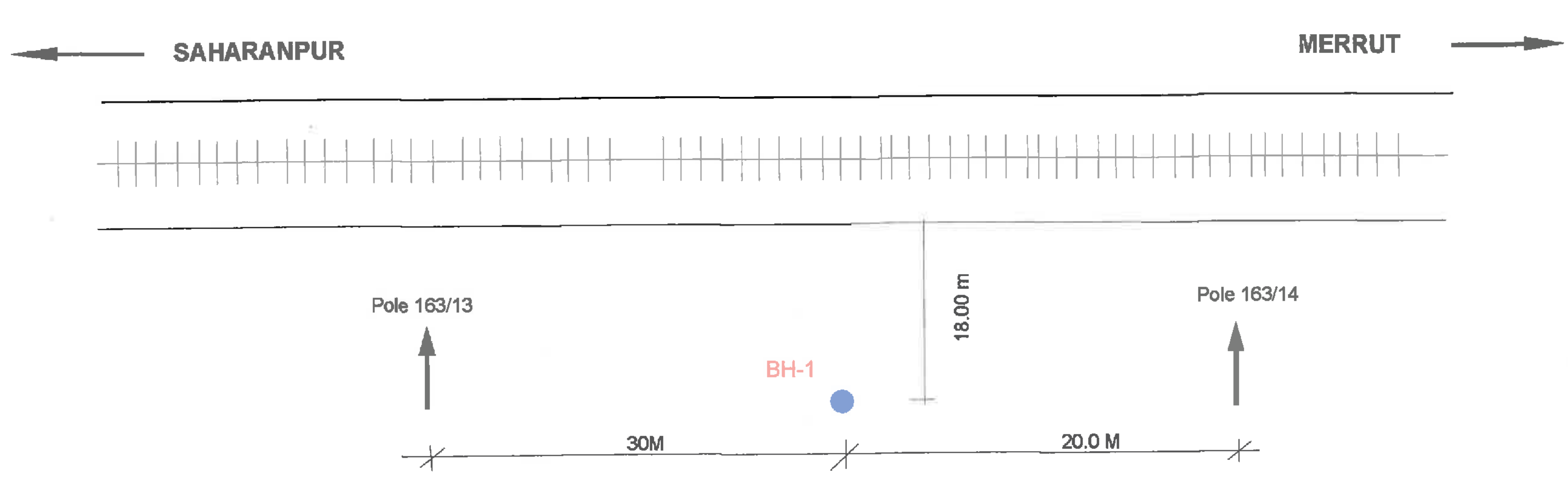
Classification	Depth (m)	Standard Penetration Test Values, $N_{corrected}$
Sandy Silt with Gravel (SM-ML)		



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur	BH-1	Fig: SP-I

SOIL ENGINEERING CONSULTANTS

Job No: 1813



Interdistance @ 163/-14

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-J

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Interdistance RL: 265.670

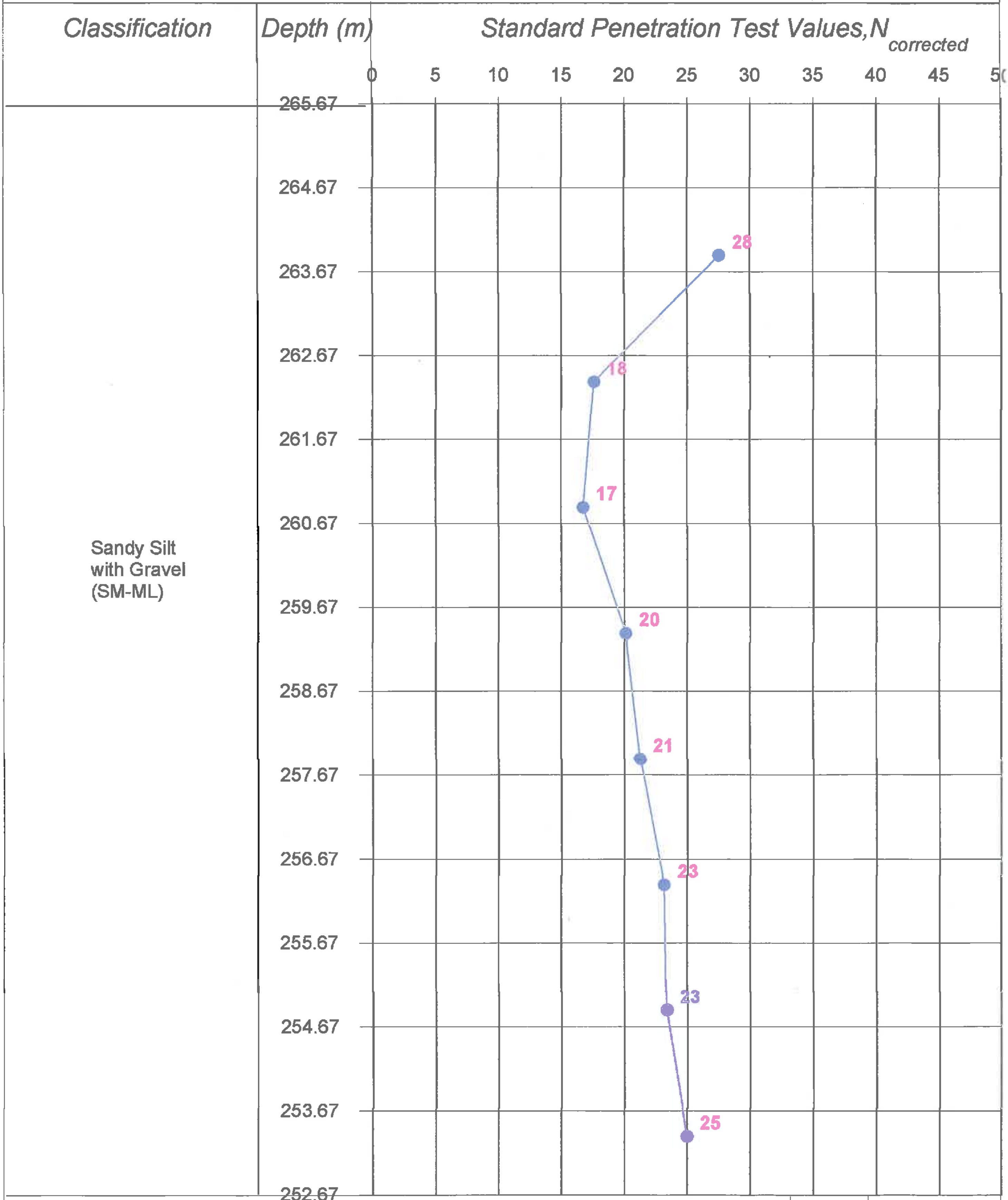
Location; 163/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 25/07/2008

Date of finish : 26/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Grain size (%) Sand	Grain size (%) Silt/clay	Density (gm/cc) r(wet)	Density (gm/cc) r(dry)	W/C W(%)	Limits (%) L.L	Limits (%) P.L	Sp.Gr	Shear Parameters Type of test	Shear Parameters C(kg/sq.cm)	Shear Parameters phi(degrees)	Cc
265.670																	
263.870	1.80	SPT		20	2	3	95				Non	Plastic					
263.170	2.50	UDS						1.8	1.63	10.43				DST	0.1	31	
262.370	3.30	SPT		15	1	3	96				Non	Plastic					
260.870	4.80	SPT		16	0	39	61				Non	Plastic					
260.170	5.50	UDS	Sandy Silt with Gravel (SM-ML)					1.83	1.63	12.61			2.66	DST	0.1	32	
259.370	6.30	SPT		21	0	5	95				Non	Plastic					
257.870	7.80	SPT		24	0	34	66				Non	Plastic					
257.170	8.50	UDS						1.86	1.63	13.78			2.66	DST	0.1	32	
256.370	9.30	SPT		28	0	3	97				Non	Plastic					
254.870	10.80	SPT		30	1	4	95				Non	Plastic					
253.370	12.30	SPT		34	4	6	90				Non	Plastic					

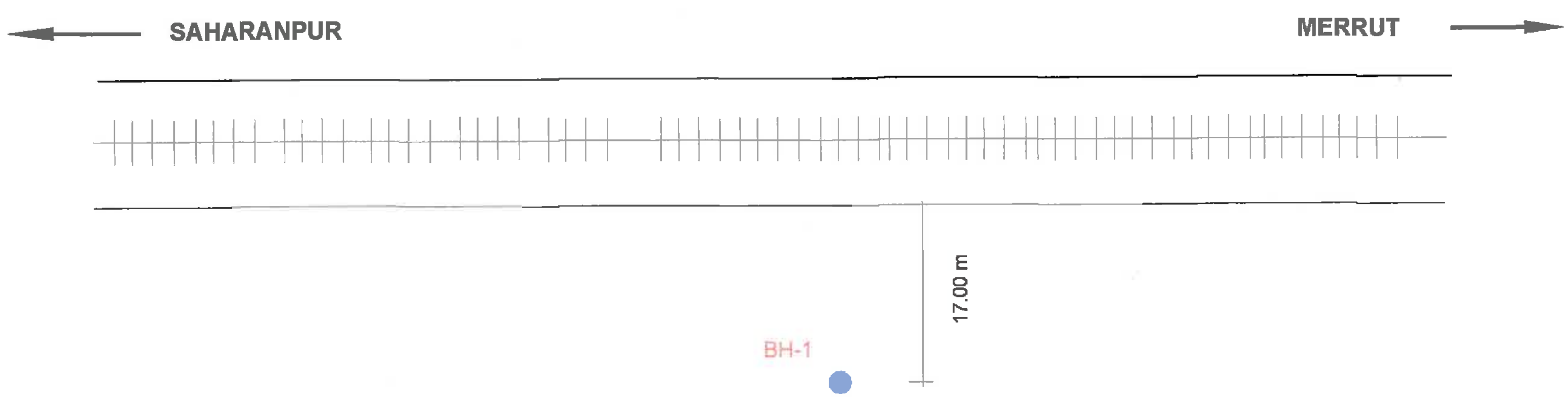
SOIL ENGINEERING CONSULTANTS | Interdistance@ 163/13-14 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-J

SOIL ENGINEERING CONSULTANTS

Job No: 1813



Interdistance @ /13-14

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-K

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

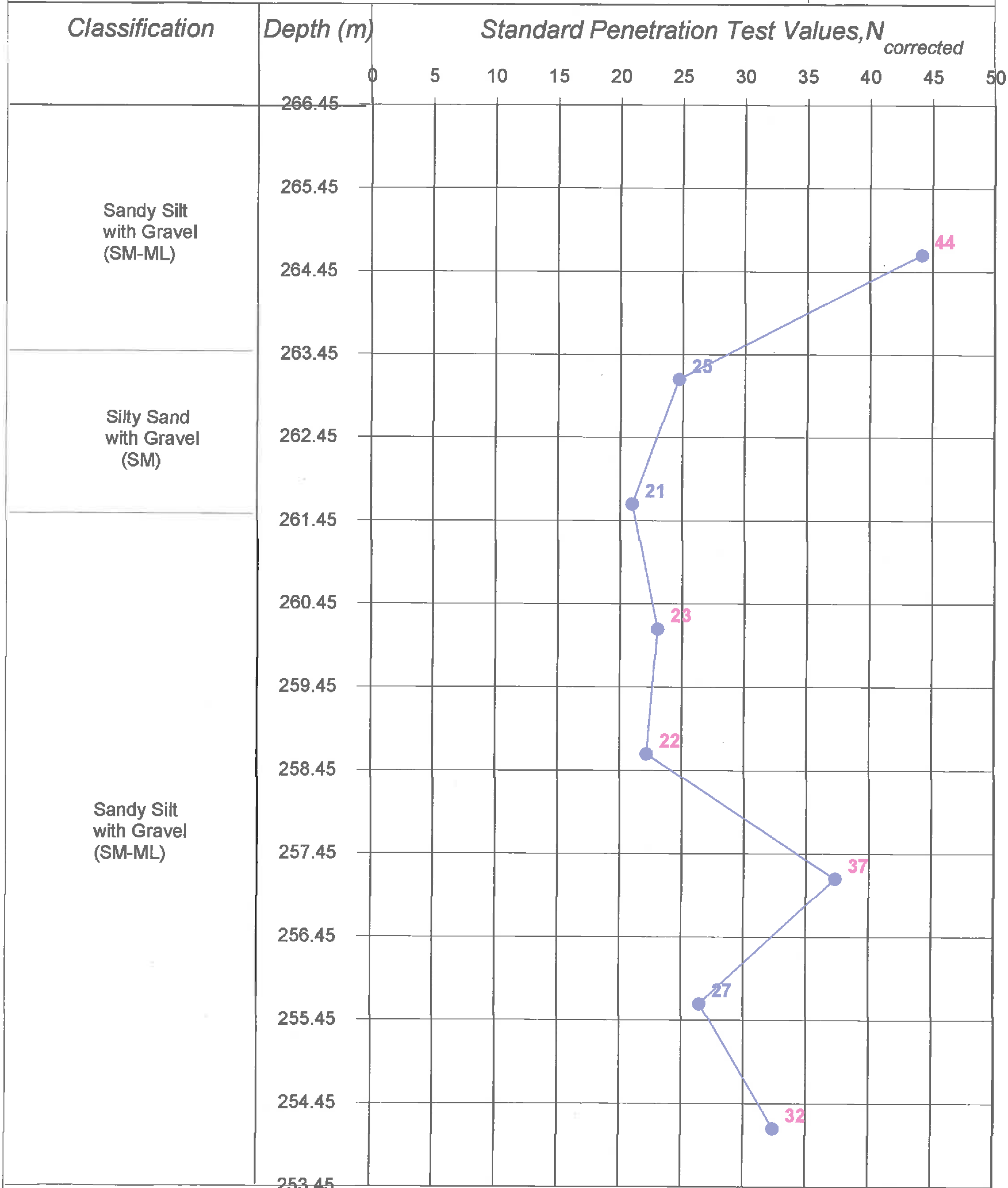
Location; 164/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 28/07/2008
Date of finish : 28/07/2008

Project No. 1813 Interdistance RL: 266.445

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot	Grain size (%)			Density (gm/cc)		W/C	Limits (%)		Sp.Gr	Shear Parameters			Cc
				Observed	Gravel	Sand	Silt/clay	r(wet)	r(dry)	W(%)	L.L	P. L		Type of test	C(kg/sq.cm)	phi(degrees)	
266.445																	
264.645	1.80	SPT	Sandy Silt with Gravel (SM-ML)	32	2	4	94				Non	Plastic					
263.945	2.50	UDS						1.86	1.65	12.64				DST	0.1	32	
263.145	3.30	SPT	Silty Sand with gravel (SM)	21	1	54	45				Non	Plastic					
261.645	4.80	SPT		20	0	35	65				Non	Plastic					
260.945	5.50	UDS						1.86	1.64	13.28			2.67	DST	0.15	32	
260.145	6.30	SPT		24	0	6	94				Non	Plastic					
258.645	7.80	SPT	Sandy Silt with Gravel (SM-ML)	25	2	34	64				Non	Plastic					
257.945	8.50	UDS						1.91	1.67	14.44				DST	0.1	33	
257.145	9.30	SPT		45	0	45	55				Non	Plastic					
255.645	10.80	SPT		34	1	38	61				Non	Plastic					
254.145	12.30	SPT		44	1	18	81				Non	Plastic					

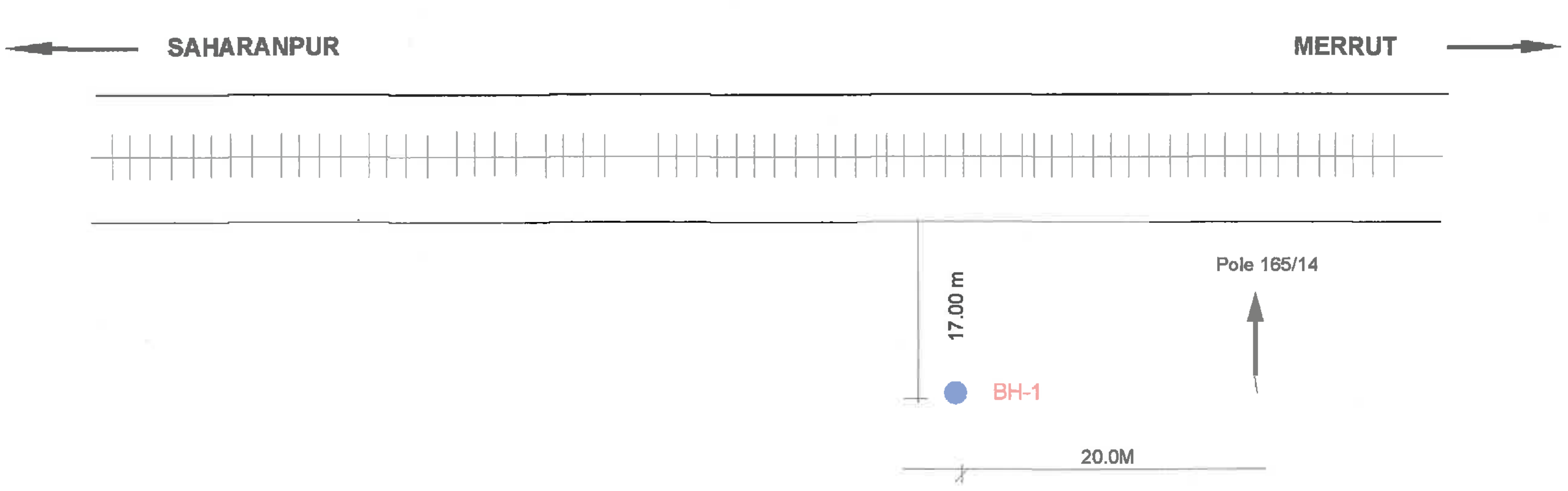
SOIL ENGINEERING CONSULTANTS | Interdistance@ 164/13-14 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-K

SOIL ENGINEERING CONSULTANTS

Job No: 1813



Interdistance @165/13-14

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-L

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

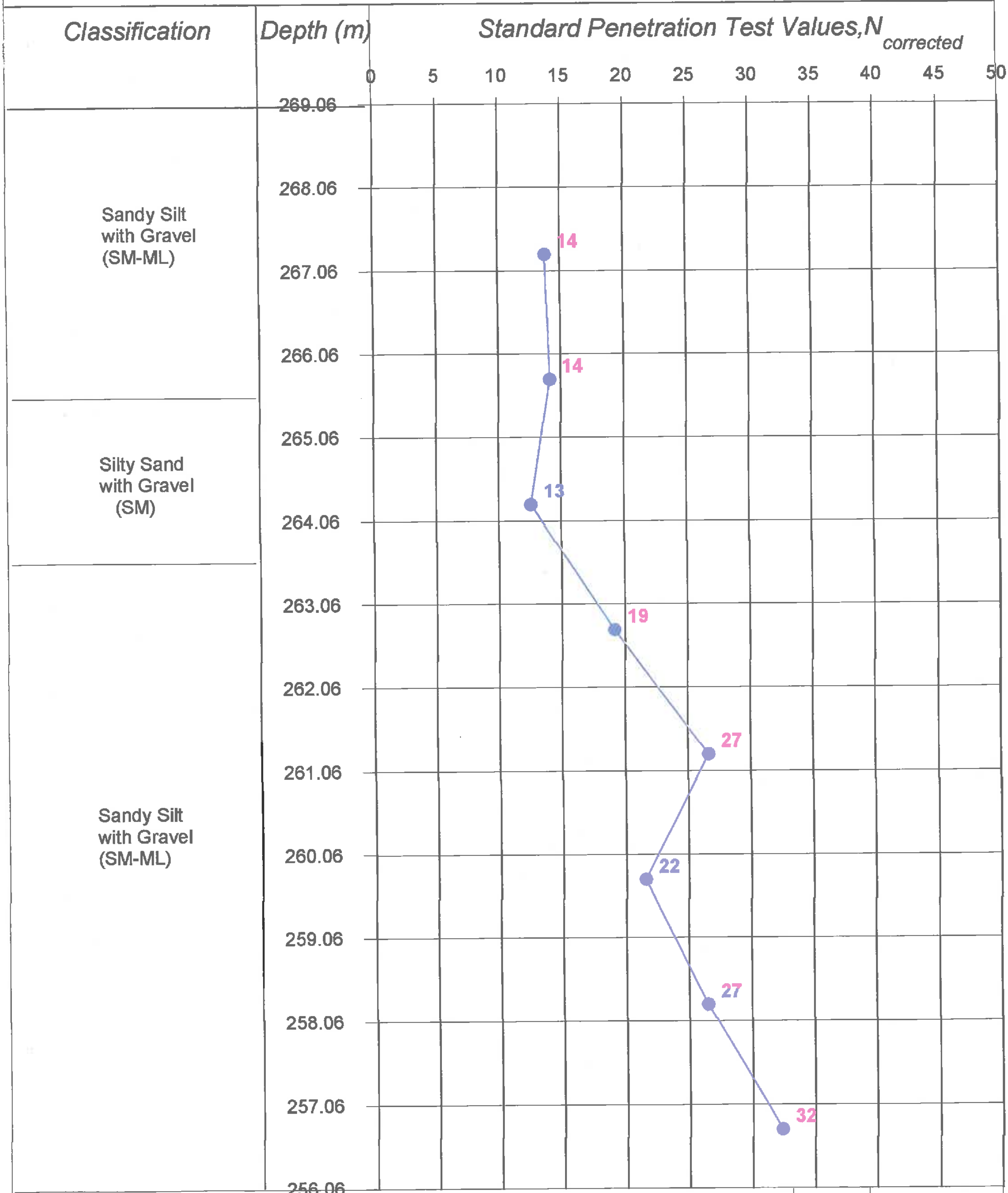
Project No. 1813 Interdistance RL: 269.060

Location; 165/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 29/07/2008
Date of finish : 30/07/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P.L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
269.060																	
267.260	1.80	SPT	Sandy Silt with Gravel (SM-ML)	10	0	6	94				Non	Plastic					
266.560	2.50	UDS						1.83	1.62	12.87				DST	0.1	30	
265.760	3.30	SPT		12	1	8	91				Non	Plastic					
264.260	4.80	SPT	Silty Sand (SM)	12	0	52	48				Non	Plastic					
263.560	5.50	UDS	Sandy Silt with Gravel (SM-ML)					1.84	1.61	14.11			2.66	DST	0.1	30	
262.760	6.30	SPT		20	0	22	78				Non	Plastic					
261.260	7.80	SPT		30	0	17	83				Non	Plastic					
260.560	8.50	UDS						1.87	1.62	15.43				DST	0.15	32	
259.760	9.30	SPT		26	0	42	58				Non	Plastic					
258.260	10.80	SPT		34	0	20	80				Non	Plastic					
256.760	12.30	SPT		44	1	31	68				Non	Plastic					

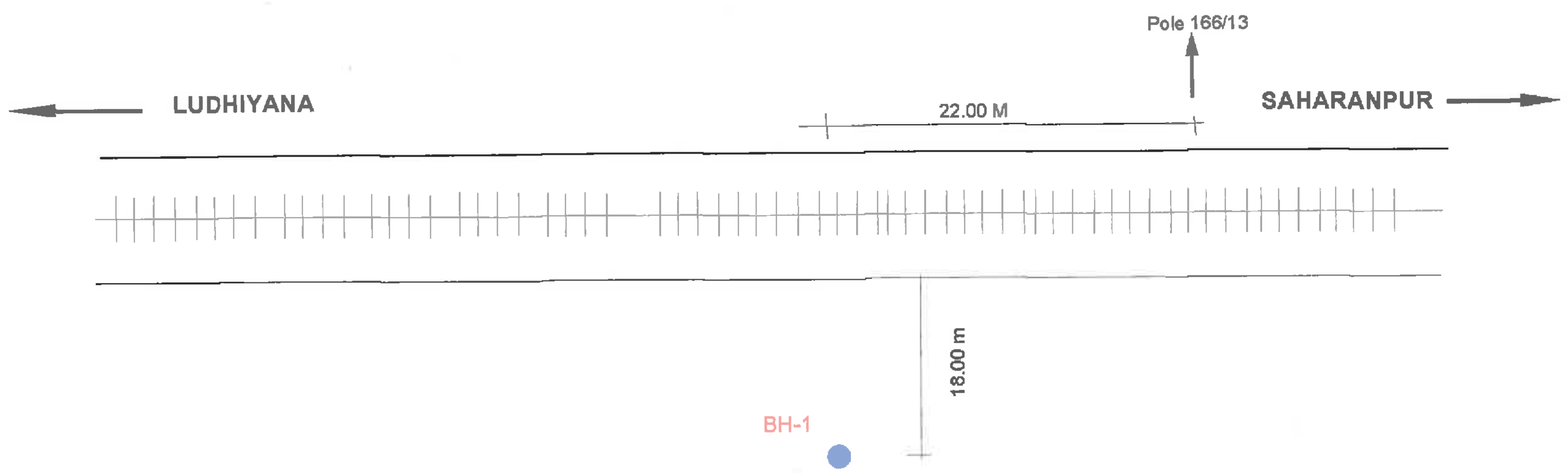
SOIL ENGINEERING CONSULTANTS	Interdistance@ 165/13-14	Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur	BH-1	Fig: SP-L

SOIL ENGINEERING CONSULTANTS

Job No: 1813



Interdistance @166/13-14

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan-M

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

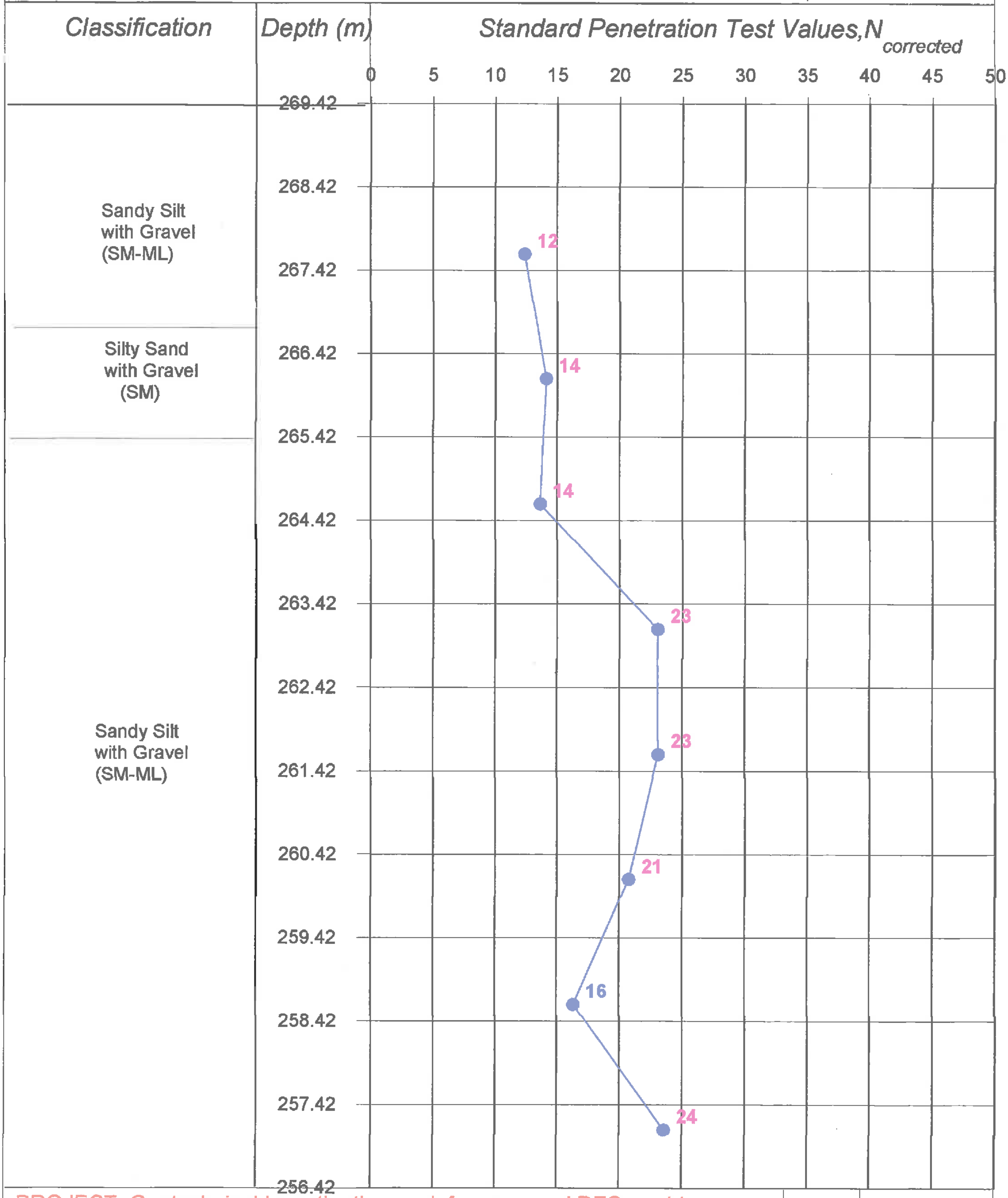
Project No. 1813 Interdistance RL: 269.420

Location; 166/13-14
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 01/08/2008
Date of finish : 02/08/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P. L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
269.420																	
267.620	1.80	SPT	Sandy Silt with Gravel (SM-ML)	9	0	8	92				Non	Plastic					
266.920	2.50	UDS						1.78	1.58	12.87				DST	0.15	30	
266.120	3.30	SPT	Silty Sand with gravel (SM)	12	1	53	46				Non	Plastic					
264.620	4.80	SPT	Sandy Silt with Gravel (SM-ML)	13	0	29	71				Non	Plastic					
263.920	5.50	UDS						1.84	1.61	14.11			2.66	DST	0.1	32	
263.120	6.30	SPT		24	0	6	94				Non	Plastic					
261.620	7.80	SPT		26	0	40	60				Non	Plastic					
260.920	8.50	UDS						1.89	1.64	15.47			2.65	DST	0.1	32	
260.120	9.30	SPT		25	0	29	71				Non	Plastic					
258.620	10.80	SPT		21	0	34	66				Non	Plastic					
257.120	12.30	SPT		32	0	48	52				Non	Plastic					

SOIL ENGINEERING CONSULTANTS | Interdistance@ 166/13-14 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-M

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

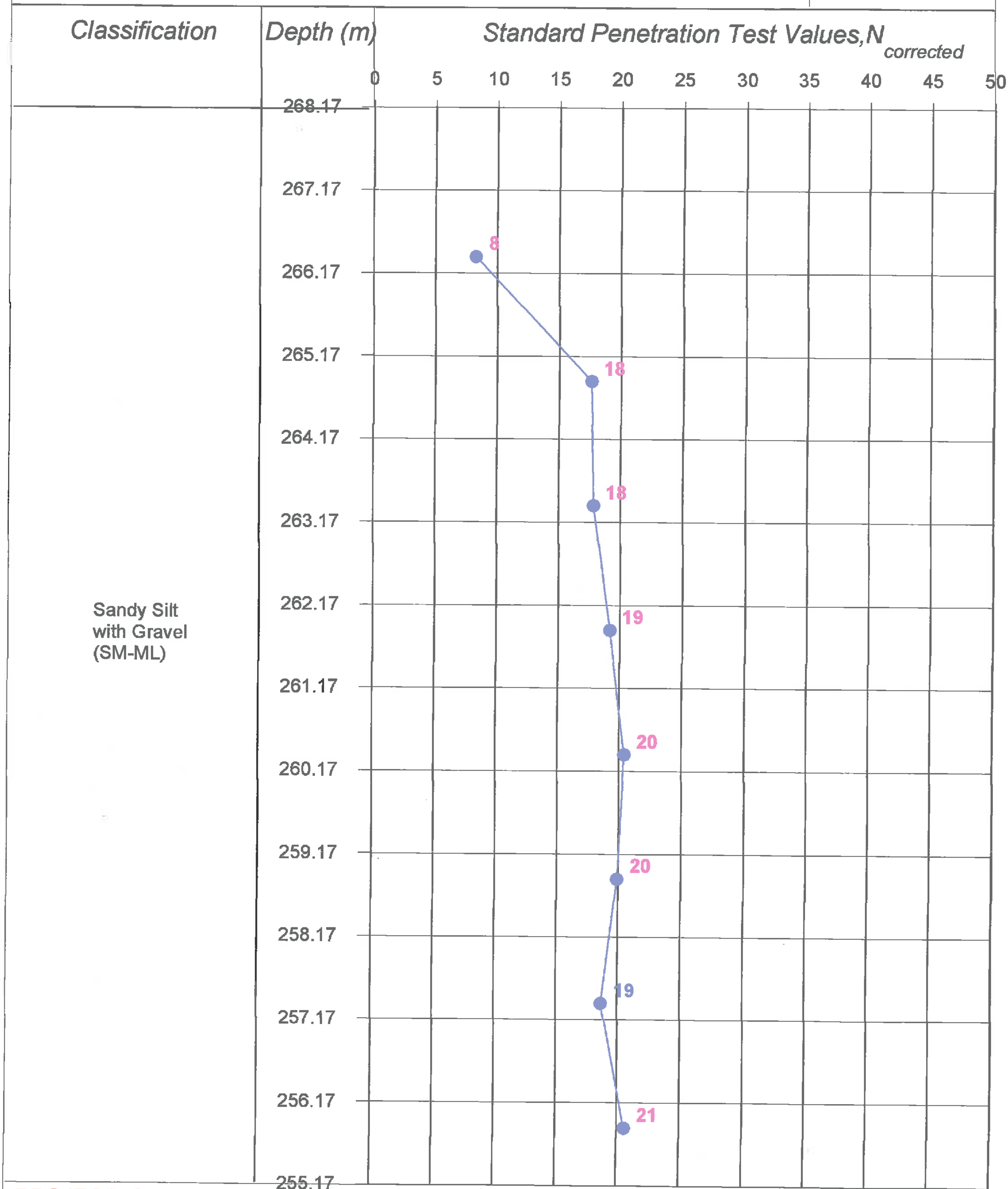
Project No. 1813 Bridge : 208 RL: 268.168

Location; 167/10-11
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 02/08/2008
Date of finish : 03/08/2008

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot (Observed)	Grain size (%)			Density (gm/cc)		W/C	Limits (%)		Sp.Gr	Shear Parameters			Cc
					Gravel	Sand	Silt/clay	r(wet)	r(dry)	W(%)	L.L	P.L		Type of test	C(kg/sq.cm)	phi(degrees)	
268.168																	
266.368	1.80	SPT		6	2	3	95				Non	Plastic					
265.668	2.50	UDS						1.73	1.55	11.89				DST	0.1	29	
264.868	3.30	SPT		15	0	17	83				Non	Plastic					
263.368	4.80	SPT		17	0	46	54				Non	Plastic					
262.668	5.50	UDS	Sandy Silt with Gravel (SM-ML)					1.86	1.64	13.42			2.66	DST	0.1	32	
261.868	6.30	SPT		20	0	27	73				Non	Plastic					
260.368	7.80	SPT		23	1	4	95				Non	Plastic					
259.668	8.50	UDS						1.87	1.62	15.61				DST	0.15	32	
258.868	9.30	SPT		24	0	28	72				Non	Plastic					
257.368	10.80	SPT		24	0	12	88				Non	Plastic					
255.868	12.30	SPT		28	0	17	83				Non	Plastic					

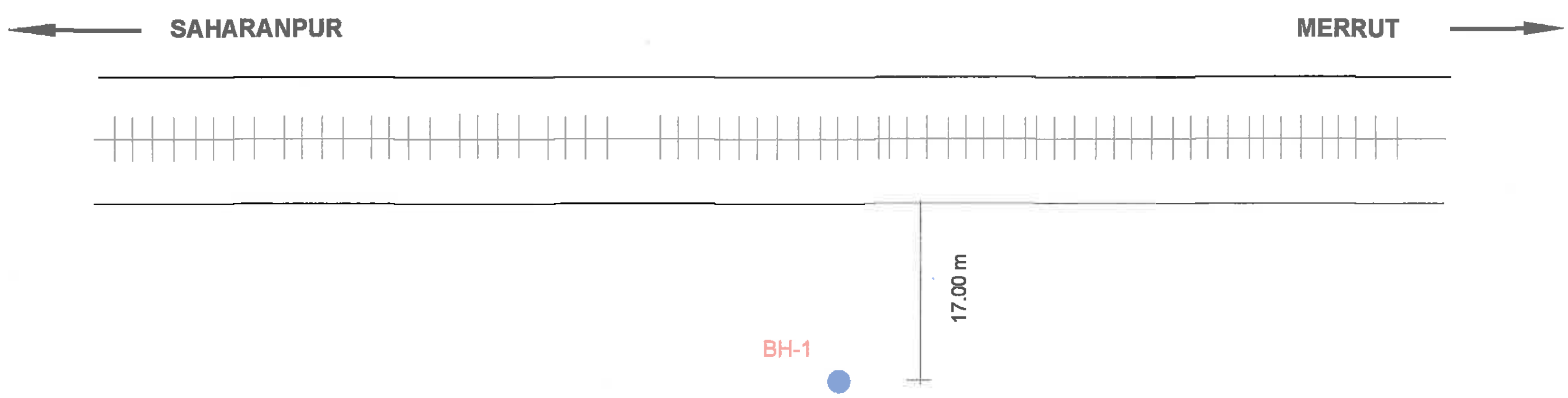
SOIL ENGINEERING CONSULTANTS | Br : 208 @ 167/10-11 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-N

SOIL ENGINEERING CONSULTANTS

Job No: 1813



Interdistance @168/10-11

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Fig: Plan- O

BORE LOG

PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur

Project No. 1813 Interdistance RL: 267.890

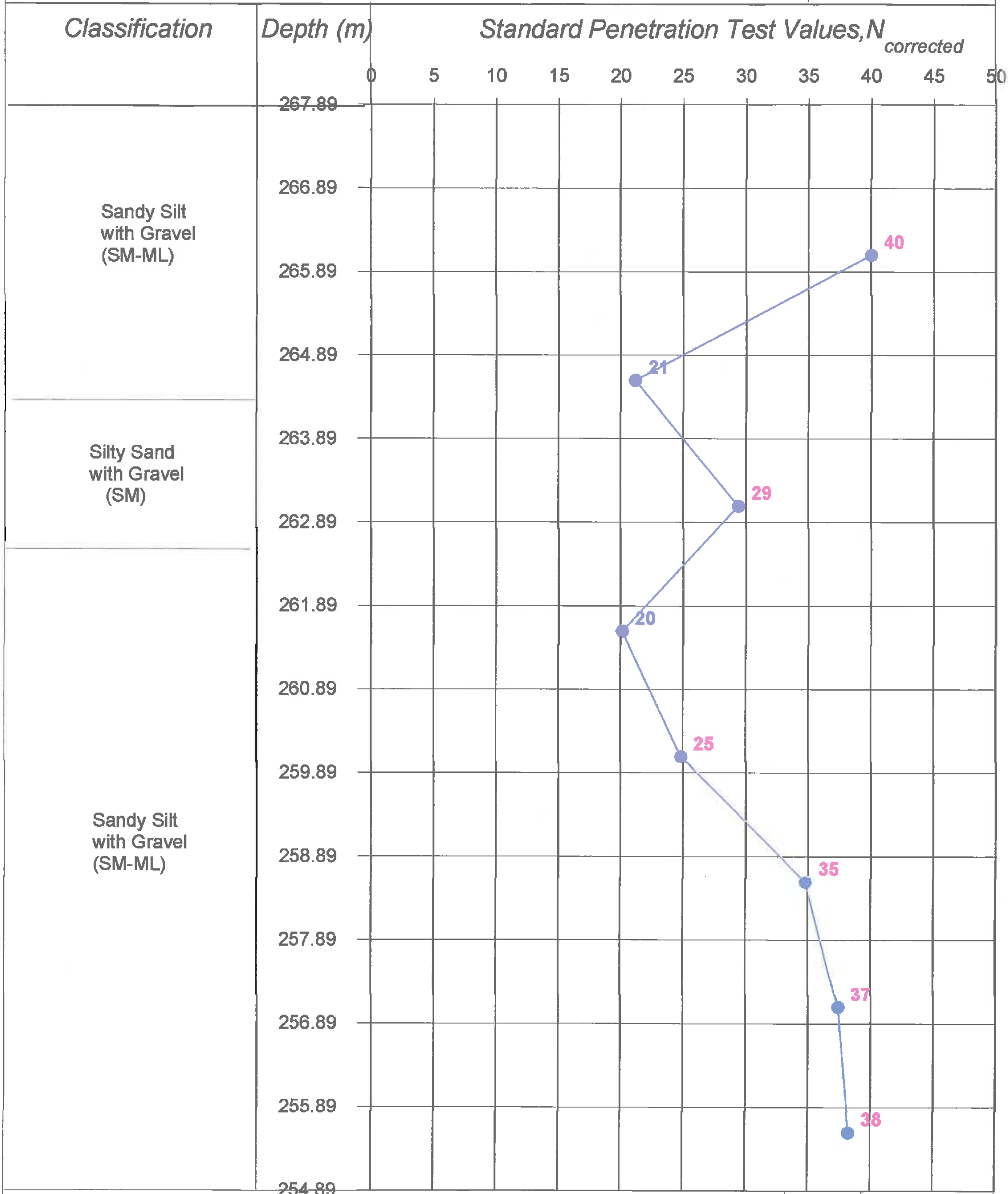
Location; 168/10-11
BH No.: 1
Depth : 12.00
Depth of Water table : Not Met

Date of start : 03/08/2008
Date of finish : 04/08/2008

SOIL ENGINEERING CONSULTANTS

Reduced Level	Depth (m)	Type of sample	Soil Classification	S.P.T Plot Observed	Grain size (%) Gravel	Sand	Silt/clay	Density (gm/cc) r(wet)	r(dry)	W/C W(%)	Limits (%) L.L	P.L	Sp.Gr	Shear Parameters Type of test	C(kg/sq.cm)	phi(degrees)	Cc
267.890				0.00													
266.090	1.80	SPT	Sandy Silt with Gravel (SM-ML)	29	1	4	95				Non	Plastic					
265.390	2.50	UDS						1.86	1.66	11.93				DST	0.15	31	
264.590	3.30	SPT		18	0	2	98				Non	Plastic					
263.090	4.80	SPT	Silty Sand with gravel (SM)	28	0	52	48				Non	Plastic					
262.390	5.50	UDS						1.93	1.72	12.47			2.65	DST	0.1	32	
261.590	6.30	SPT		21	0	32	68				Non	Plastic					
260.090	7.80	SPT		28	0	9	91				Non	Plastic					
259.390	8.50	UDS	Sandy Silt with Gravel (SM-ML)					1.96	1.73	13.21				DST	0.1	33	
258.590	9.30	SPT		42	0	26	74				Non	Plastic					
257.090	10.80	SPT		48	0	39	61				Non	Plastic					
255.590	12.30	SPT		52	0	11	89				Non	Plastic					

SOIL ENGINEERING CONSULTANTS | Interdistance@ 168/10-11 | Project No: 1813



PROJECT: Geotechnical Investigation work for proposed DFC corridor from Ludhiyana to Saharanpur | BH-1 | Fig: SP-O

CHAPTER - 24

"Alignment",

Location - Existing Km. - 174/450

24.1 LOCATION OF STRUCTURE:
Alignment at Existing Km. 174/450

24.2 BOREHOLE DESCRIPTIONS:
(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *8.00m* below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

24.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.20	NIL	0.0017	NIL	0.0011	0.008
	6.00	8.30	NIL	0.0019	NIL	0.0012	0.011

24.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

24.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.4	118	116	149	659	0.1	2.8	808	1293
Requirement as per IS 456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

24.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	08.00
	3.00	14.00
	4.50	16.00
	6.00	17.50

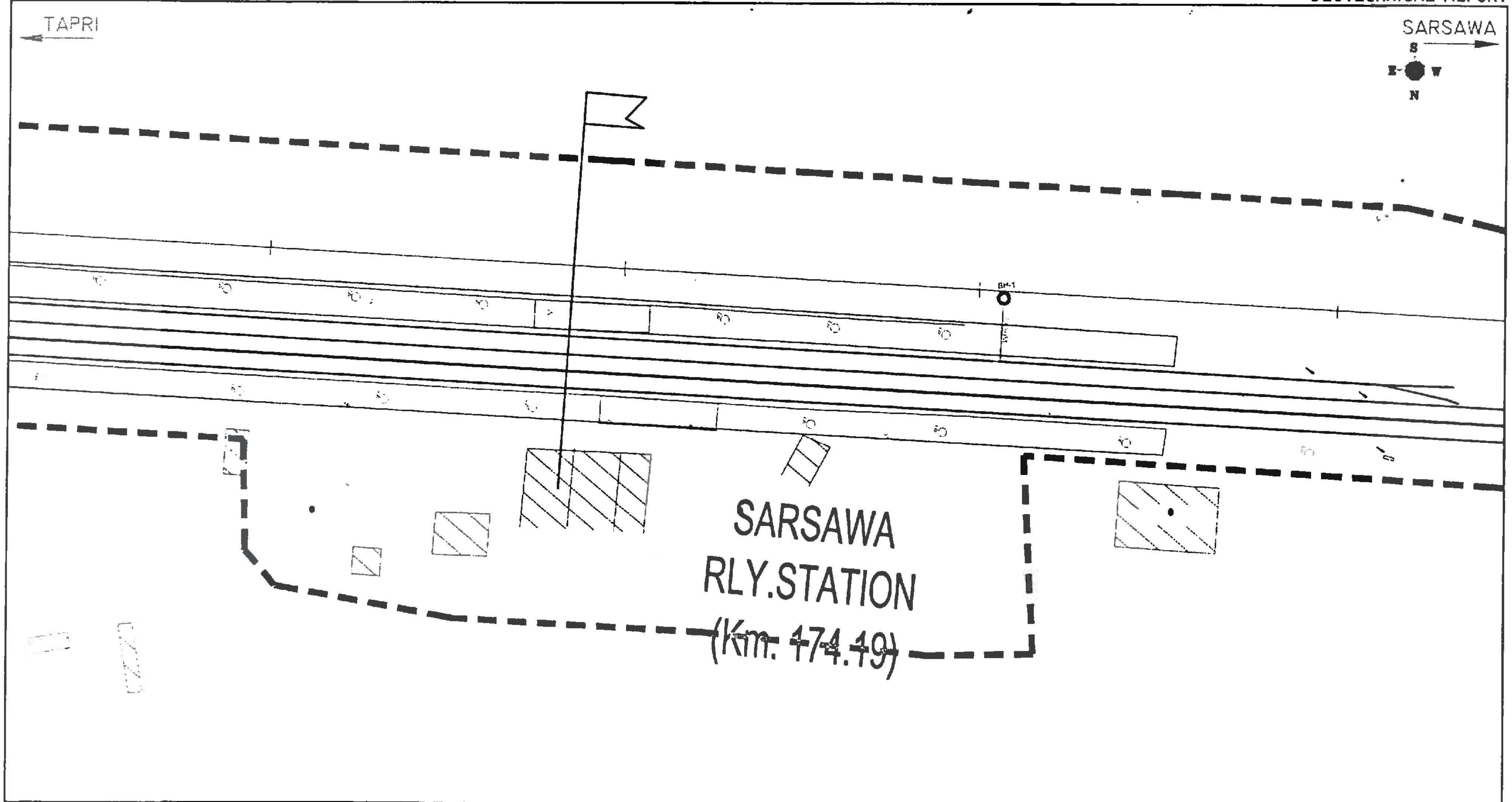
24.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

24.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED ALIGNMENT AT CH. 174/450	RL OF BH-I =270.793	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR ALIGNMENT AT CHAINAGE 174/450

Project :	Chainage 174/450	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		29.12.2009 to 29.12.2009	1	1	08.00 m.	12.00mtr	-

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm^2	ϕ degree
0.00	-	-	-	Silty Sand	2.35	39.03	48.26	10.36	0.00	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
1.50	9	1.46	13.14	Silty Sand	3.62	44.25	43.45	8.68	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	0.00	6.96	54.74	38.30	0.00	0.00	0.00	23	NIL	NP	1.70	13.62	1.50	2.68	0.00	29.5
4.50	12	1.09	13.08	Silty Sand	4.21	18.83	71.95	5.01	0.00	0.00	0.00	31	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	0.00	9.48	35.26	55.26	0.00	0.00	0.00	28	NIL	NP	1.79	16.58	1.53	2.66	0.00	29.0
7.50	14	0.91	12.74	Silty Sand	0.00	7.39	35.03	57.53	0.05	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
10.50	19	0.80	15.10	Silty Sand	2.51	9.97	22.39	65.13	0.00	0.00	0.00	22	NIL	NP	-	-	-	-	-	-
12.00	24	0.75	16.50	Silty Sand	0.00	5.05	20.46	74.49	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-

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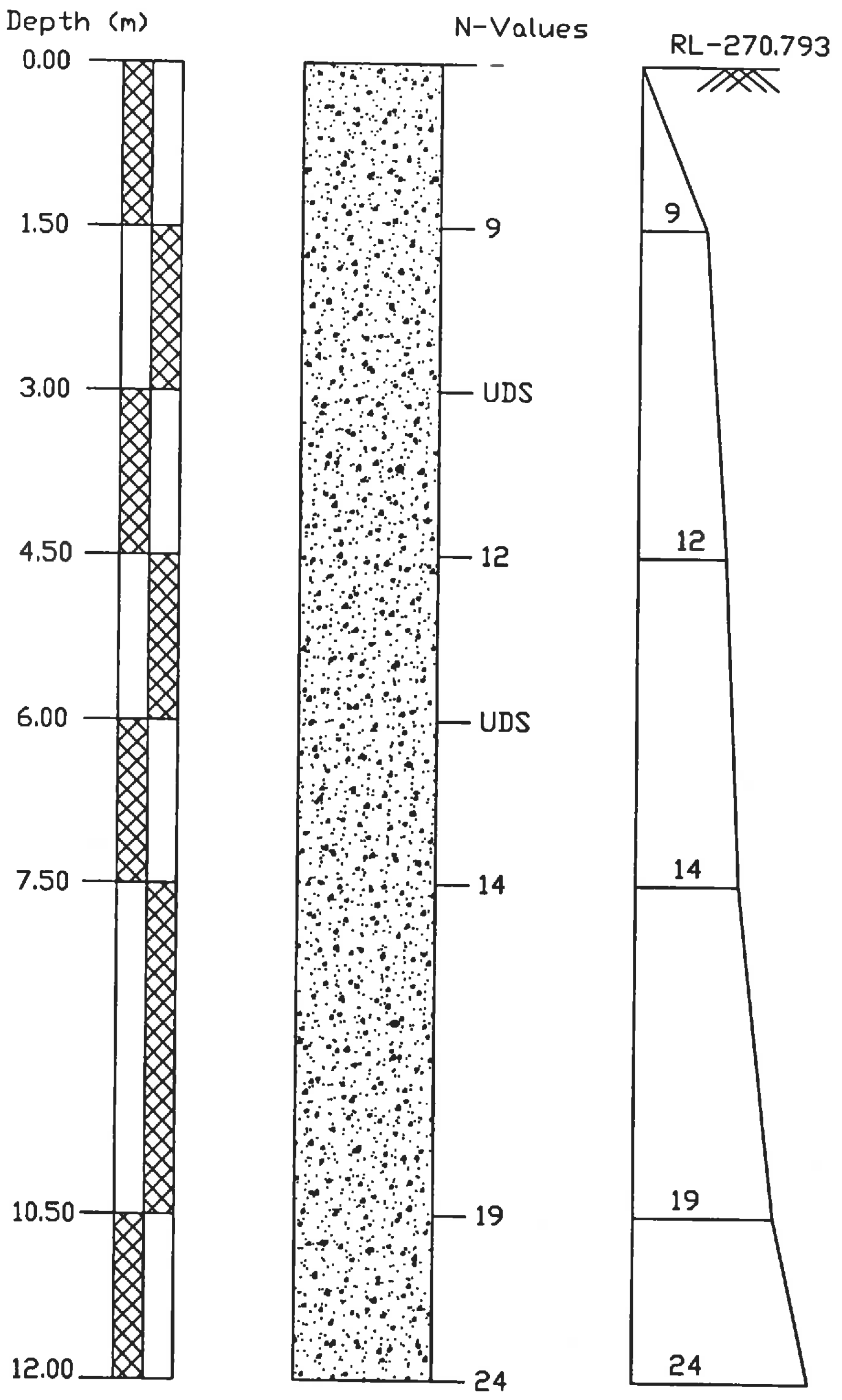
BORELOG OF BH-1 AT EXISTING KM-174/450 FOR ALIGNMENT,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 174 450 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	29.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.78
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.70
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c\, s_c\, d_c\, i_c + q\,(N_q - 1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c\, s_c\, d_c'\, i_c + q\,(N'_q - 1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N'_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

ANNEXURE - III

Bearing capacity factors :

ϕ	29.50
N_c	29.20
N_q	17.63
N_γ	21.25

ϕ'	20.76
N'_c	15.73
N'_q	7.05
N'_γ	6.22

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.17	1.09	1.09
2	3.00	3.00	1.34	1.17	1.17
3	4.50	3.00	1.51	1.26	1.26
4	6.00	3.00	1.69	1.34	1.34

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	24.83	8.44	8.44
2	3.00	3.00	8.00	44.59	15.58	15.58
3	4.50	3.00	8.00	47.85	16.72	16.72
4	6.00	3.00	8.00	51.11	17.86	17.86

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

Location	Alignment
Chainage	174/450
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	8.00
Average N value	13
Settlement for 10 t/m2 (mm)	26.00
Total Settlement (mm)	20.80
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	15.1

Footing Depth (m)	3.00
SBC (t/m2)	14.00
Average N value	13
Settlement for 10 t/m2 (mm)	26.00
Total Settlement (mm)	36.40
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	24.2

Footing Depth (m)	4.50
SBC (t/m2)	16.00
Average N value	13
Settlement for 10 t/m2 (mm)	26.00
Total Settlement (mm)	41.60
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	24.6

Footing Depth (m)	6.00
SBC (t/m2)	17.50
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	38.50
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	20.9

CHAPTER - 23

"Alignment",

Location - Existing Km. - 177/02-03

CONSULTING Engineers Group Ltd.

23.1 LOCATION OF STRUCTURE:
Alignment at Existing Km. 177/02-03

23.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *7.50m* below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 4.50	Sandy Silt with Clay	Loose
	4.50 to 6.00	Sandy Silt with Clay	Medium Dense
	6.00 to 10.50	Clayey Silt with Sand	Medium Dense
	10.50 to 12.00	Sandy Silt with Clay	Medium Dense

23.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	7.70	NIL	0.0021	NIL	0.0012	0.044
	6.00	7.90	NIL	0.0022	NIL	0.0012	0.062

23.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	13.00
	6.00	18.00

23.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.8	138	109	168	689	0.1	2.1	860	1352
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

23.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	08.50
	3.00	12.00
	4.50	13.00
	6.00	14.00

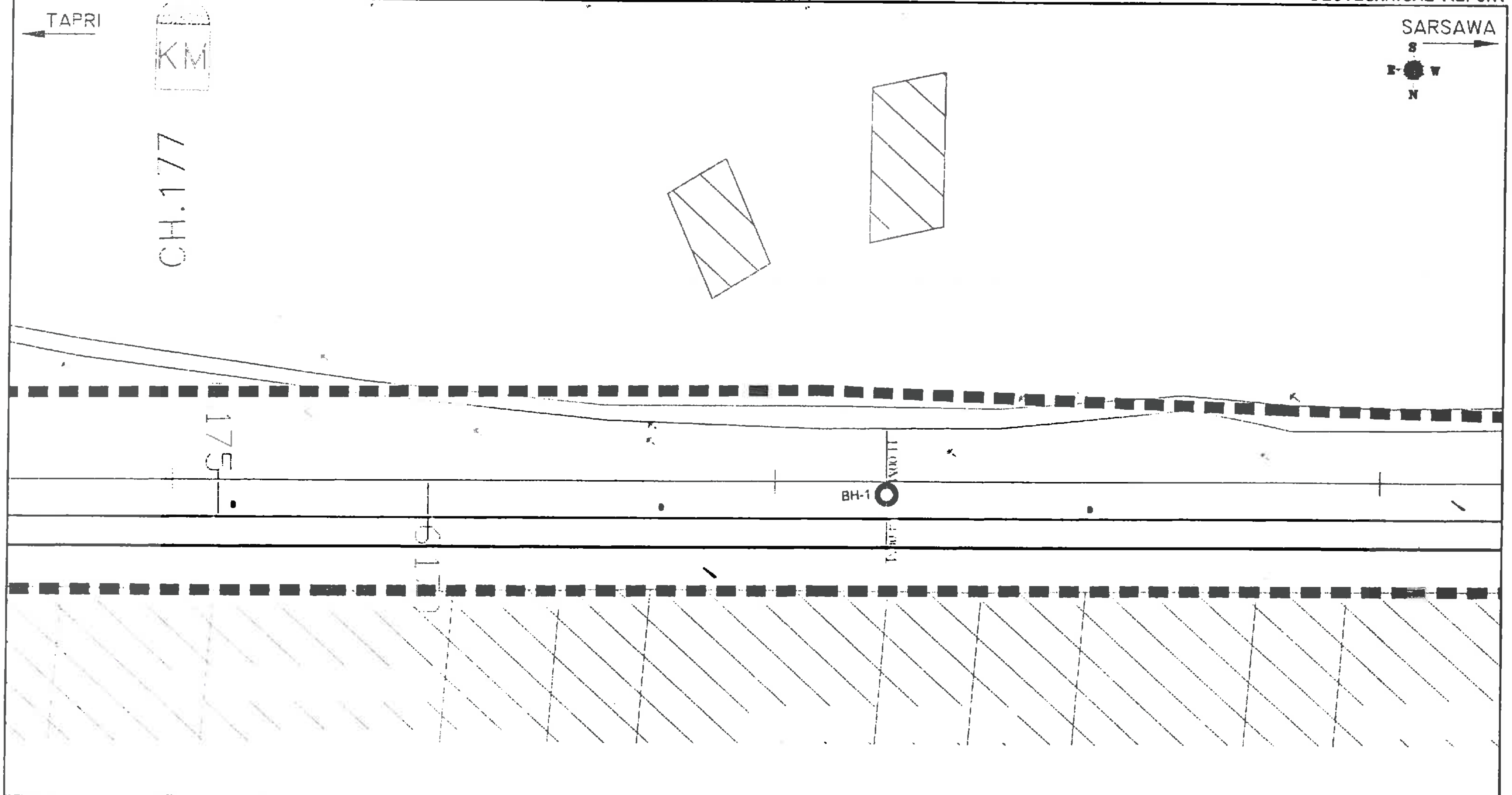
23.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

23.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED ALIGNMENT
AT CH. 177/02/03

RL OF BH-I =274.093

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-
CONSULTING
ENGINEERS GROUP LTD.
E-12,Moji Colony,Malviya Nagar Jaipur-17
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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR ALIGNMENT AT CHAINAGE 177/02-03

Project :	Chainage 177/02-03	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		28.12.2009 to 28.12.2009	1	1	07.50 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm²	Shear Strength: ϕ degree
0.00	-	-	-	Sandy Silt with Clay	14.26	62.06	15.62	6.35	1.15	0.56	0.00	35	23	12	-	-	-	-	-	-
0.50	DS	-	-	Sandy Silt with Clay	12.36	64.70	16.36	5.24	0.68	0.66	0.00	34	24	10	-	-	-	-	-	-
1.50	7	1.43	10.01	Sandy Silt with Clay	16.23	65.65	13.56	4.03	0.27	0.26	0.00	36	23	13	-	-	-	-	-	-
3.00	UDS	-	-	Sandy Silt with Clay	11.95	56.49	24.34	4.32	1.60	1.30	0.00	33	23	10	1.85	18.81	1.56	2.64	0.12	19.0
4.50	11	1.06	11.66	Sandy Silt with Clay	9.26	45.17	42.69	2.77	0.11	0.00	0.00	27	19	8	-	-	-	-	-	-
6.00	UDS	-	-	Clayey Silt with sand	16.96	70.86	10.27	1.22	0.19	0.50	0.00	38	24	14	1.92	20.69	1.59	2.67	0.15	17.0
7.50	14	0.89	12.46	Clayey Silt with sand	14.86	77.71	6.08	1.31	0.04	0.00	0.00	39	27	12	-	-	-	-	-	-
10.50	17	0.77	13.09	Sandy Silt with Clay	10.12	67.76	20.25	1.52	0.25	0.10	0.00	33	25	8	-	-	-	-	-	-
12.00	27	0.73	17.36	Sandy Silt with Clay	8.95	69.79	20.07	1.19	0.00	0.00	0.00	32	25	7	-	-	-	-	-	-

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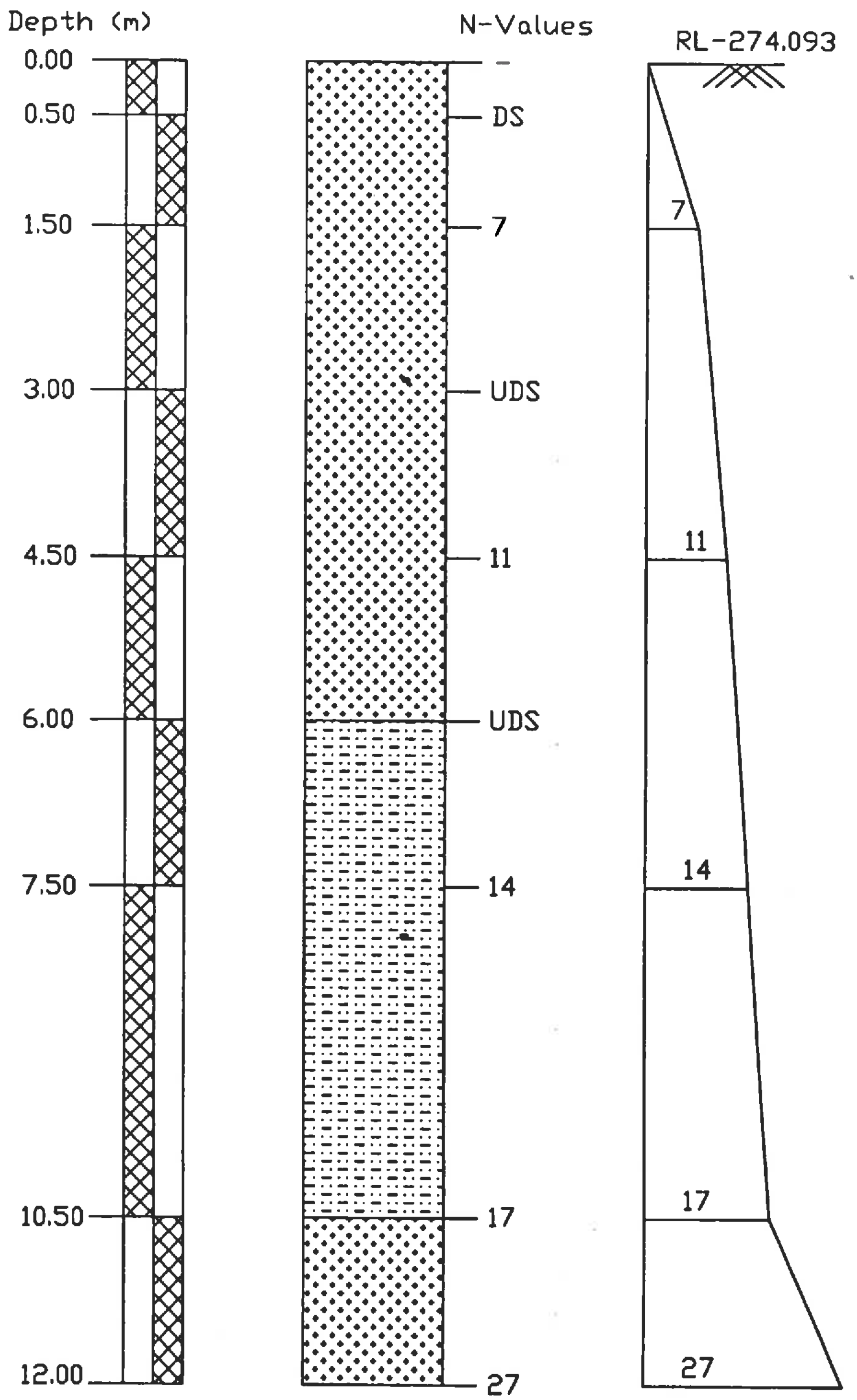
BORELOG OF BH–1 AT EXISTING KM–177/02–03 FOR ALIGNMENT,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
(dotted pattern)	SANDY SILT WITH CLAY
(dashed pattern)	CLAYEY SILT WITH SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 177 2-3 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	17.00
Cohesion (c in t/m2)	1.50
Void ratio (e)	0.68
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.90
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	17.00
N_c	12.52
N_q	4.92
N_γ	3.75

ϕ'	11.58
N'_c	9.18
N'_q	2.93
N'_γ	1.67

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.14	1.07	1.07
2	3.00	3.00	1.27	1.14	1.14
3	4.50	3.00	1.41	1.20	1.20
4	6.00	3.00	1.54	1.27	1.27

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	13.08	6.34	8.70
2	3.00	3.00	8.00	18.41	8.95	12.26
3	4.50	3.00	8.00	19.90	9.68	13.26
4	6.00	3.00	8.00	21.40	10.41	14.26

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 177/2-3**

BH No. (A1)

Depth of foundation = 1.5 m

Length of footing (L) = 8.0 m

Width of footing (B) = 3.0 m

Initial effective stress at mid of layer Po = 6.75 t/m^2

Concentrated load P = 8.50 t/m^2

Incerase in pressure at mid of layer ΔP = $P \times I_B$

I_B = 0.21

ΔP = 1.8 t/m^2

Compression Index Cc = 0.12

Thickness of clay layer H = 4.5 m

Initial Void ratio e_o = 0.68

$$\frac{Po + \Delta p}{Po} = 1.26444$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.03275 m

= 32.7535 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{0.5}$ = 0.31

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.91

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 23.8 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 177/2-3**

BH No. (A1)

Depth of foundation		=	3.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	9.45	t/m^2
Concentrated load P		=	12.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.5	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.68	

$$\frac{Po + \Delta p}{Po} = 1.26667$$

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.033 m

= 32.9986 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.61

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.83

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 21.9 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 177/2-3**

BH No. (A1)

Depth of foundation		=	4.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of lay	Po	=	12.69	t/m^2
Concentrated load P		=	13.00	t/m^2
Incerase in pressure at mid of laye	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.7	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.68	
	$\frac{Po + \Delta p}{Po}$	=	1.21513	

Settlement of clay layer $$S_f = \frac{Cc}{1+eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0272002 m

= 27.20017 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.92

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.74

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 16.1 mm

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 177/2-3**

BH No. (A1)

Depth of foundation		=	6.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of lay	Po	=	15.51	t/m^2
Concentrated load *P*		=	14.00	t/m^2
Incerase in pressure at mid of laye	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.9	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.68	

$$\frac{Po + \Delta p}{Po} = 1.1895551$$

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0242308 m

= 24.230756 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$(LB)^{\wedge 0.5}/D$ = 0.82

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.68

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 13.2 mm

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CHAPTER – 22

"Alignment",

Location – Existing Km. – 180/15-17

22.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 180/15-17

22.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *7.00m* below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 1.50	Silty Sand with Gravels	Loose
	1.50 to 3.00	Silty Sand with Gravels	Medium Dense
	3.00 to 12.00	Silty Sand	Medium Dense

22.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	7.90	NIL	0.0022	NIL	0.0011	0.062
	6.00	8.10	NIL	0.0021	NIL	0.0011	0.072

22.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

22.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.3	136	96	150	746	0.3	3.3	901	1397
Requirement as per IS 456 / Mosrth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

22.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	10.00
	3.00	19.00
	4.50	20.00
	6.00	21.50

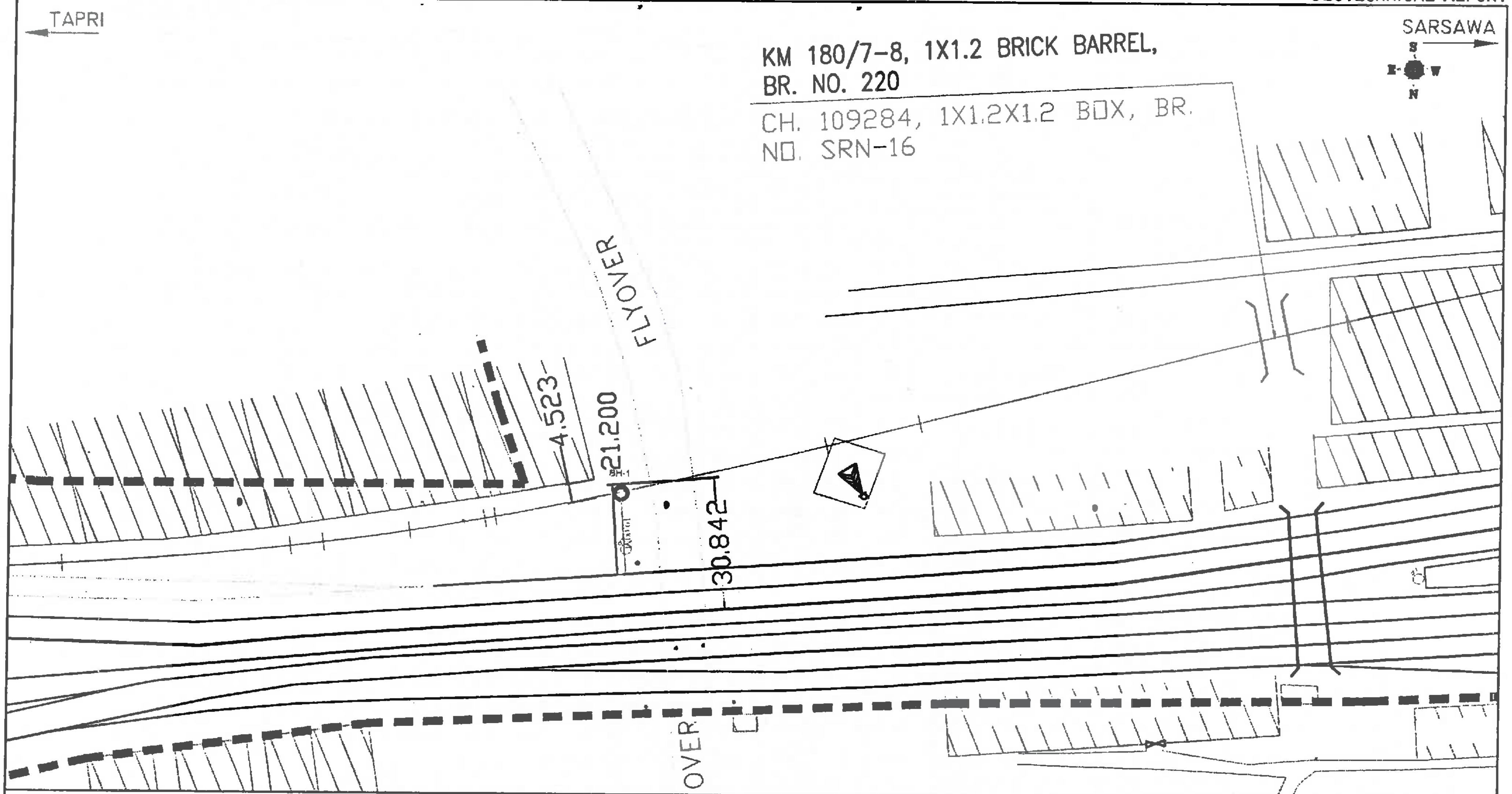
22.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

22.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED ALIGNMENT AT CH. 180/15/17	RL OF BH-I =273.683	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Maji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR ALIGNMENT AT CHAINAGE 180/15-17

Project :	Chainage 180/17-19			Date of Testing	Location at		B.H. No.		Depth of Water Table			Termination Depth			Surface Elevation					
				26.12.2009 to 26.12.2009	1		1		07.00 m.			12.00mtr								
Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity		
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc		c kg/cm^2	ϕ degree
0.00	-	-	-	Silty Sand with Gravels	2.65	11.54	32.38	46.15	0.69	6.59	0.00	23	NIL	NP	-	-	-	-	-	-
1.00	DS	-	-	Silty Sand with Gravels	3.21	4.92	36.54	48.62	1.22	5.49	0.00	24	NIL	NP	-	-	-	-	-	-
1.50	10	1.44	14.40	Silty Sand with Gravels	0.00	6.75	38.19	46.82	0.39	7.85	0.00	25	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	0.00	8.78	39.06	52.02	0.14	0.00	0.00	29	NIL	NP	1.82	14.36	1.59	2.69	0.00	27.0
4.50	15	1.07	16.05	Silty Sand	0.00	8.66	22.60	67.28	0.42	1.04	0.00	27	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	3.68	19.92	12.36	62.37	0.35	1.32	0.00	26	NIL	NP	1.92	16.39	1.65	2.65	0.00	29.0
7.50	16	0.89	14.24	Silty Sand	4.66	23.75	8.82	60.54	0.52	1.71	0.00	29	NIL	NP	-	-	-	-	-	-
10.50	21	0.77	15.59	Silty Sand	4.26	8.41	38.18	47.39	0.46	1.30	0.00	28	NIL	NP	-	-	-	-	-	-
12.00	24	0.73	16.26	Silty Sand	4.66	5.21	26.57	58.74	0.43	4.39	0.00	29	NIL	NP	-	-	-	-	-	-

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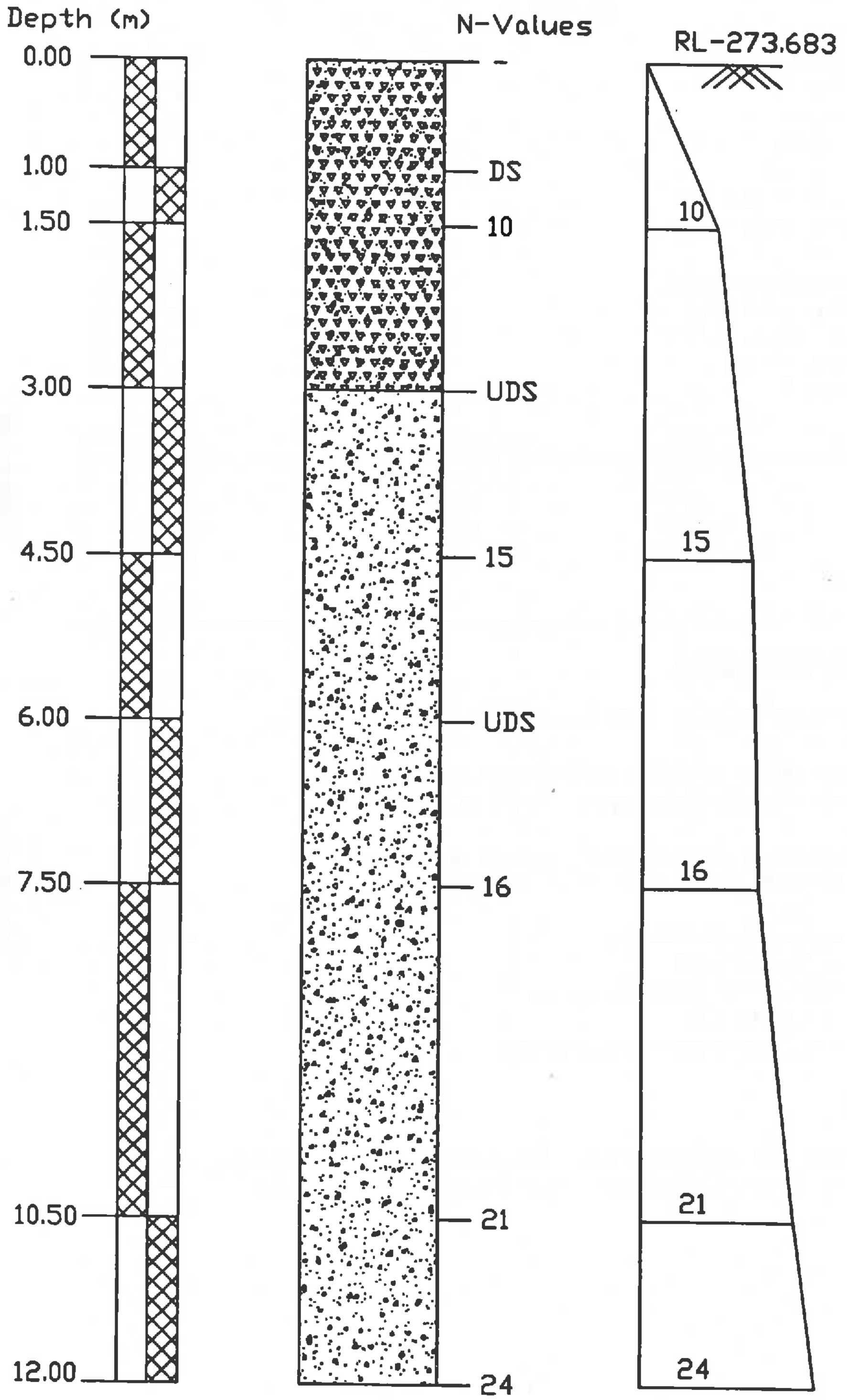
BORELOG OF BH–1 AT EXISTING KM–180/15–17 FOR ALIGNMENT,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND WITH GRAVELS
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 180 15-17 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.69
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.82
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$q_d = c\, N_c\, s_c\, d_c\, i_c + q\,(N_q-1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$

The ultimate net bearing capacity in case of local shear failure is given by

$q'_d = (2/3)\, c\, N'_c\, s_c\, d_c\, i_c + q\,(N'_q-1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N'_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	19.09	6.77	10.46
2	3.00	3.00	8.00	34.08	12.42	18.92
3	4.50	3.00	[illegible]	36.47	13.29	20.24
4	6.00	3.00	8.00	38.86	14.16	21.57

CONSULTING Engineers Group Ltd.

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Alignment
Chainage	180/15-17
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	10.00
Average N value	15
Settlement for 10 t/m2 (mm)	22.00
Toatl Settlement (mm)	22.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	16.0

Footing Depth (m)	3.00
SBC (t/m2)	19.00
Average N value	16
Settlement for 10 t/m2 (mm)	19.00
Toatl Settlement (mm)	36.10
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	24.0

Footing Depth (m)	4.50
SBC (t/m2)	20.00
Average N value	16
Settlement for 10 t/m2 (mm)	20.00
Toatl Settlement (mm)	40.00
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	23.7

Footing Depth (m)	6.00
SBC (t/m2)	21.50
Average N value	16
Settlement for 10 t/m2 (mm)	20.00
Toatl Settlement (mm)	43.00
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	23.4

CHAPTER – 21

"Alignment",

Location – Existing Km. – 181/15-17

21.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 181/15-17

21.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *7.00m* below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 3.00	Silty Sand with Gravels	Loose
	3.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

21.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.60	NIL	0.0028	NIL	0.0013	0.088
	6.00	8.40	NIL	0.0021	NIL	0.0013	0.062

21.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

21.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (μS/cm)
Test Result	7.1	132	105	163	853	0.3	1.2	1036	1562
Requirement as per IS 456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

21.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	09.00
	3.00	16.00
	4.50	20.00
	6.00	21.50

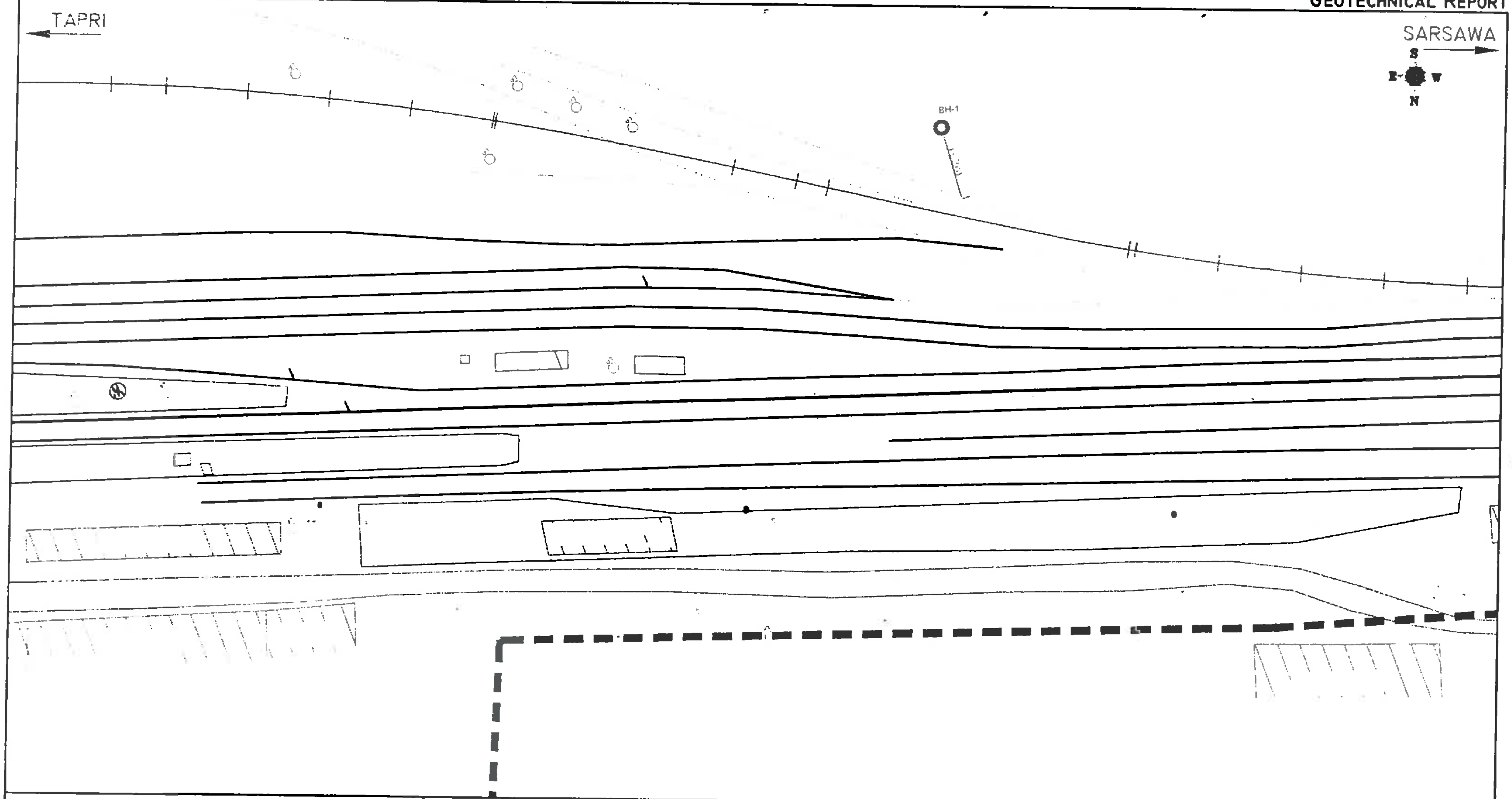
21.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

21.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED ALIGNMENT AT CH. 181/15/17

RL OF BH-I =274.443

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-
CONSULTING ENGINEERS GROUP LTD.
E-12,Maji Colony,Malviya Nagar Jaipur-17
Tel: +91-141- 2520899, 2521899, 2520556
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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR ALIGNMENT AT CHAINAGE 181/15-17

Project :	Chainage 181/17-19			Date of Testing	Location at	B.H. No.	Depth of Water Table				Termination Depth			Surface Elevation					
				25.12.2009 to 25.12.2009	1	1	07.00 m.				12.00mtr								
Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Silty Sand with Gravels	0.00	8.03	32.15	50.65	1.25	7.56	0.36	24	NIL	NP	-	-	-	-	-	-
2.00	DS	-	-	Silty Sand with Gravels	0.00	10.11	30.26	52.45	1.12	5.64	0.42	25	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	2.65	13.25	30.33	49.66	0.90	3.21	0.00	27	NIL	NP	1.82	14.63	1.59	2.68	0.00	27.0
4.50	13	1.07	13.91	Silty Sand	0.00	8.05	40.85	49.81	0.39	0.90	0.00	28	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	0.00	9.97	62.62	25.64	0.65	1.12	0.00	26	NIL	NP	1.89	15.63	1.63	2.67	0.00	29.0
7.50	17	0.89	15.07	Silty Sand	0.00	7.53	68.45	20.80	0.42	2.80	0.00	29	NIL	NP	-	-	-	-	-	-
10.50	24	0.78	16.86	Silty Sand	2.26	9.57	39.11	48.06	0.66	0.34	0.00	29	NIL	NP	-	-	-	-	-	-
12.00	27	0.73	17.36	Silty Sand	0.00	5.65	70.20	20.77	0.25	3.13	0.00	26	NIL	NP	-	-	-	-	-	-

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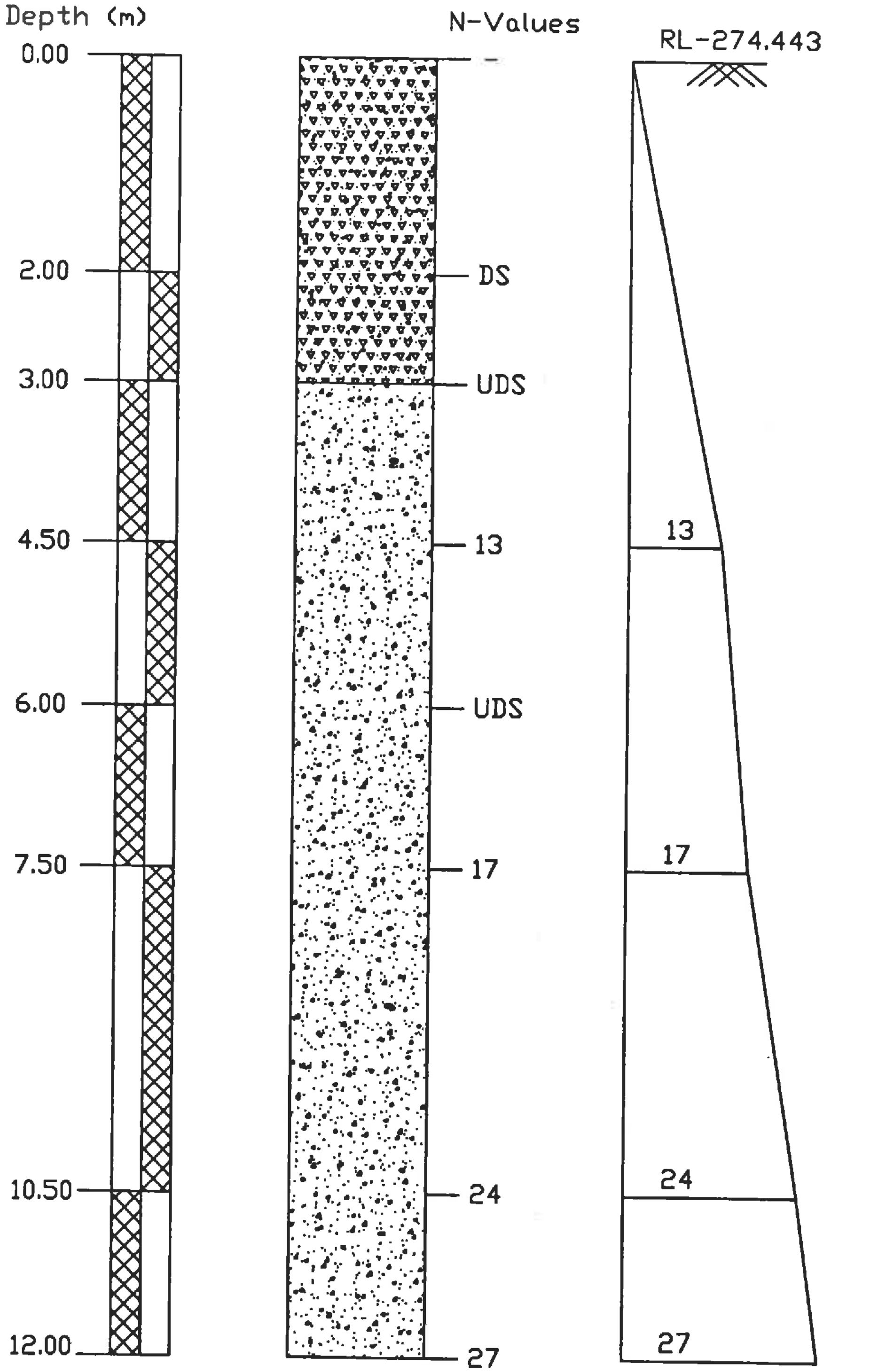
BORELOG OF BH-1 AT EXISTING KM-181/15-17 FOR ALIGNMENT,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND WITH GRAVELS
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 181 15-17 **BH-1**

Type of footing

1. Continuous Strip
2. Rectangular
3. Square
4. Circular

Rectangular **2**

Angle of internal friction (ϕ °)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.69
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.82
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c\, s_c\, d_c\, i_c + q\, (N_q-1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c\, s_c\, d_c\, i_c + q\, (N'_q-1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N'_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

Where,

$d_c = 1 + 0.2\, (D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\, (D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	19.09	6.77	10.46
2	3.00	3.00	8.00	34.08	12.42	18.92
3	4.50	3.00	8.00	36.47	13.29	20.24
4	6.00	3.00	8.00	38.86	14.16	21.57

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Alignment
Chainage	181/15-17
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	9.00
Average N value	10
Settlement for 10 t/m2 (mm)	36.00
Total Settlement (mm)	32.40
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	23.6

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	14
Settlement for 10 t/m2 (mm)	23.00
Total Settlement (mm)	36.80
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	24.4

Footing Depth (m)	4.50
SBC (t/m2)	20.00
Average N value	15
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	42.00
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	24.9

Footing Depth (m)	6.00
SBC (t/m2)	21.50
Average N value	15
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	45.15
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	24.6

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CHAPTER – 20

"Alignment",

Location – Existing Km. – 186/00-01

20.1 LOCATION OF STRUCTURE:

Alignment at Existing Km. 186/00-01

20.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***6.00m*** below EGL

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 3.00	Clayey Silt with Sand	Loose
	3.00 to 4.50	Sandy Silt with Clay	Loose
	4.50 to 6.00	Sandy Silt with Clay	Medium Dense
	6.00 to 7.50	Silty Sand with Clay	Medium Dense
	7.50 to 12.00	Sandy Silt with Clay	Medium Dense

20.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.10	NIL	0.0021	NIL	0.0012	0.049
	6.00	8.30	NIL	0.0020	NIL	0.0012	0.052

20.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	14.00
	6.00	14.00

20.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.7	72	136	119	708	0.4	5.4	884	1392
Requirement as per IS:456 / Mosrth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

20.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	08.00
	3.00	12.00
	4.50	13.00
	6.00	14.00

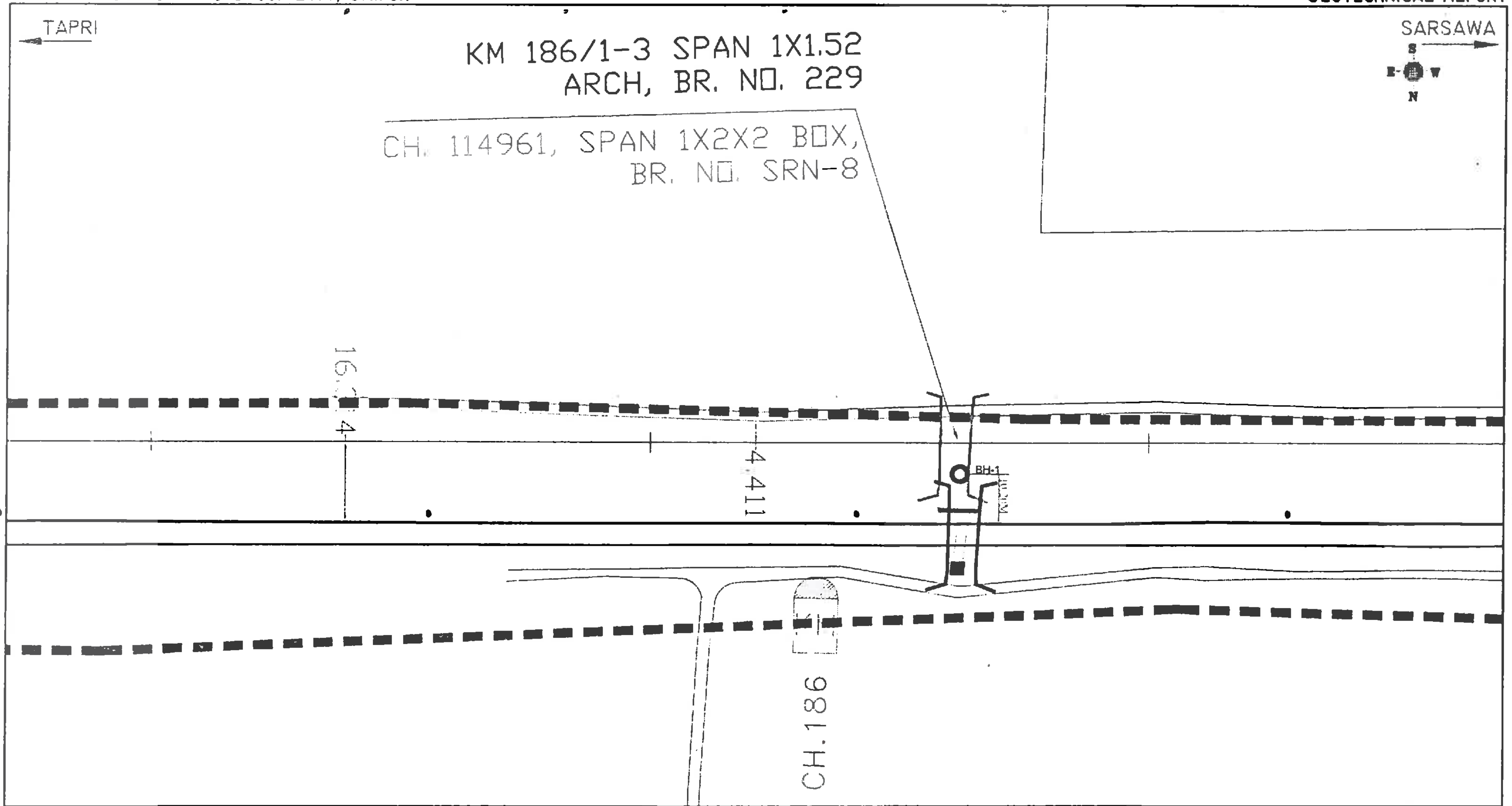
20.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

20.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED ALIGNMENT AT CH. 186/0-I	RL OF BH-I =277.133	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax. 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR ALIGNMENT AT CHAINAGE 186/00-01

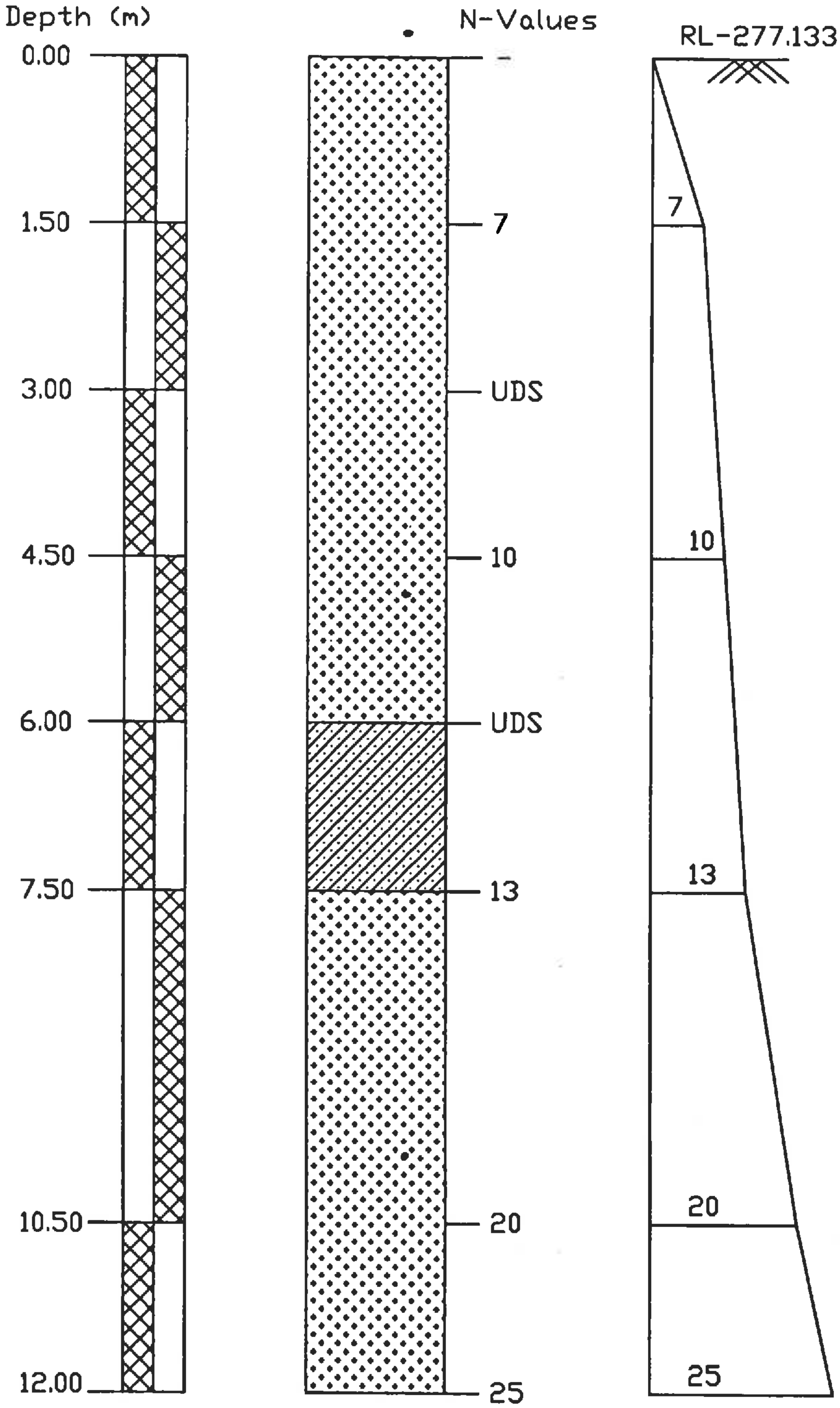
Project :	Chainage 186/01-02	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		22.12.2009 to 22.12.2009	1	1	06.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm²	ϕ degree
0.00	-	-	-	Clayey Silt with Sand	12.36	74.03	6.58	2.24	1.14	3.65	0.00	34	24	10	-	-	-	-	-	-
1.50	7	1.44	10.08	Clayey Silt with Sand	12.76	75.41	5.06	1.43	0.83	4.51	0.00	37	26	11	-	-	-	-	-	-
3.00	UDS	-	-	Sandy Silt with Clay	11.84	69.40	14.69	0.56	0.27	3.24	0.00	35	25	10	1.78	13.28	1.57	2.63	0.13	18.0
4.50	10	1.08	10.80	Sandy Silt with Clay	9.85	66.91	15.54	0.91	0.63	0.76	5.40	30	22	8	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand with Clay	11.36	14.46	71.22	2.96	0.00	0.00	0.00	32	22	10	1.86	19.67	1.55	2.62	0.11	19
7.50	13	0.90	11.70	Sandy Silt with Clay	12.53	68.52	13.31	0.56	0.10	4.98	0.00	34	23	11	-	-	-	-	-	-
10.50	20	0.78	15.30	Sandy Silt with Clay	13.00	67.07	17.76	1.01	0.46	0.70	0.00	35	24	11	-	-	-	-	-	-
12.00	25	0.74	16.75	Sandy Silt with Clay	14.36	61.07	20.36	2.14	1.12	0.95	0.00	36	24	12	-	-	-	-	-	-

CONSULTING Engineers Group Ltd.

BORELOG OF BH-1 AT EXISTING KM-186/0-1 FOR ALIGNMENT,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SANDY SILT WITH CLAY
	SILTY SAND WITH CLAY

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 186/0-1 BH-1

Type of footing

1. Continuous Strip
2. Rectangular
3. Square
4. Circular

Rectangular **2**

Angle of internal friction (ϕ °)	19.00
Cohesion (c in t/m2)	1.10
Void ratio (e)	0.69
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.86
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c\, s_c\, d_c\, i_c + q\,(N_q - 1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c\, s_c\, d_c\, i_c + q\,(N'_q - 1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N'_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)^*\mathrm{SQRT}(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)^*\mathrm{SQRT}(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Bearing capacity factors :

ϕ	19.00
N_c	14.06
N_q	5.91
N_γ	4.84

ϕ'	12.99
N'_c	9.92
N'_q	3.35
N'_γ	2.08

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.14	1.07	1.07
2	3.00	3.00	1.28	1.14	1.14
3	4.50	3.00	1.42	1.21	1.21
4	6.00	3.00	1.56	1.28	1.28

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	13.17	6.15	8.25
2	3.00	3.00	8.00	19.50	9.17	12.27
3	4.50	3.00	8.00	21.04	9.89	13.24
4	6.00	3.00	8.00	22.58	10.62	14.21

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 186/0-1**

<u>BH No. (A1)</u>

<u>Depth of foundation</u>		=	1.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	6.68	t/m^2
Concentrated load *P*		=	8.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	1.7	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.69	
	$\frac{Po + \Delta p}{Po}$	=	1.2516854	

Settlement of clay layer $\quad S_f = \frac{Cc}{1+eo} H \log_{10} \frac{Po + \Delta P}{Po}$

	S_f	=	0.031	m
		=	31.15	mm

Correction for Depth and Rigidity of foundation on total settlement

<u>Depth Factor Calculation</u>

$D/(LB)^{\wedge 0.5}$ = 0.31

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.91

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= 0.85

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 22.68 mm

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 186/0-1**

BH No. (A1)

Depth of foundation		=	3.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	9.35	t/m^2
Concentrated load *P*		=	12.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.5	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.69	
	$\frac{Po + \Delta p}{Po}$	=	1.2696629	

Settlement of clay layer $\quad S_f = \frac{Cc}{1+ eo} H \log_{10} \frac{Po + \Delta P}{Po}$

S_f = 0.033 m

= 33.13 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.61

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.83

Rigidity Factor = $\frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$

= 0.8

Pore Pr. Correction= NA

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 22.00 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 186/0-1**

BH No. (A1)

Depth of foundation		=	4.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	12.02	t/m^2
Concentrated load *P*		=	13.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.7	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_0	=	0.69	

$$\frac{Po + \Delta p}{Po} = 1.227216$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0284126 m

= 28.41 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.92

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.78

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= NA

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 17.73 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Alignment Ch. 186/0-1**

BH No. (A1)

Depth of foundation		=	6.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	14.11	t/m^2
Concentrated load *P*		=	14.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.9	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.69	
	$\frac{Po + \Delta p}{Po}$	=	1.2083998	

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0262685 m

= 26.27 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.92

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.68

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= NA

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 14.29 mm

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'ROR'

CHAPTER – 18

"RFO (ROR)",

Location – Existing Km. - 173/400

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18.1 **LOCATION OF STRUCTURE:**
Proposed RFO (ROR) No. 173/400

18.2 **BOREHOLE DESCRIPTIONS:**

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***09.00m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1(A1)	0.00 to 7.50	Silty Sand	Loose
	7.50 to 19.50	Silty Sand	Medium Dense
	19.50 to 22.50	Silty Sand	Dense
	22.50 to 28.50	Sand	Dense
	28.50 to 30.00	Sand	Very Dense
BH-2(A2)	0.00 to 1.50	Silty Sand	Loose
	1.50 to 16.50	Silty Sand	Medium Dense
	16.50 to 28.50	Silty Sand	Dense
	28.50 to 30.00	Sand	Dense

18.3 **CHEMICAL ANALYSIS OF SOIL:**

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH*	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1 (A1)	3.00	8.20	NIL	0.0017	NIL	0.0011	0.017
	9.00	7.80	NIL	0.0017	NIL	0.0011	0.015
	18.00	8.10	NIL	0.0017	NIL	0.0011	0.019
BH-2 (A2)	6.00	8.60	0.005	0.0017	NIL	0.0011	0.011
	12.00	7.90	NIL	0.0021	NIL	0.0011	0.039
	21.00	8.20	NIL	0.0021	NIL	0.0011	0.034

18.4 **DIFFERENTIAL FREE SWELL INDEX (DFS)**

Bore Hole No.	Depth (m)	DFS Index in %
BH-1(A1)	3.00	NIL
	9.00	NIL
	18.00	NIL
BH-2 (A2)	6.00	NIL
	12.00	NIL
	21.00	NIL

18.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (μS/cm)
Test Result	7.0	135	116	159	858	0.3	2.6	1032	1562
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

18.6 PILE LOAD CARRYING CAPACITY

18.6.1 Normal Bored Cast in- situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC- 78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein.. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000.The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

Safe bearing capacity in t/m²

BH -NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m²)
BH-1 (A1)	1.50	08.50
	3.00	09.50
	4.50	11.50
	6.00	14.00
BH-2 (A2)	1.50	15.00
	3.00	16.00
	4.50	19.50

	6.00	21.00

Pile load carrying capacity in t

BH -NO.	PILE DEPTH (mtr)	PILE CARRYING CAPACITY IN TONNE
		Pile Diameter= 1.2 m
BH-1 (A1)	17.00	225.00
	20.00	290.00
	23.00	350.00
BH-2 (A2)	17.00	225.00
	20.00	290.00
	23.00	350.00

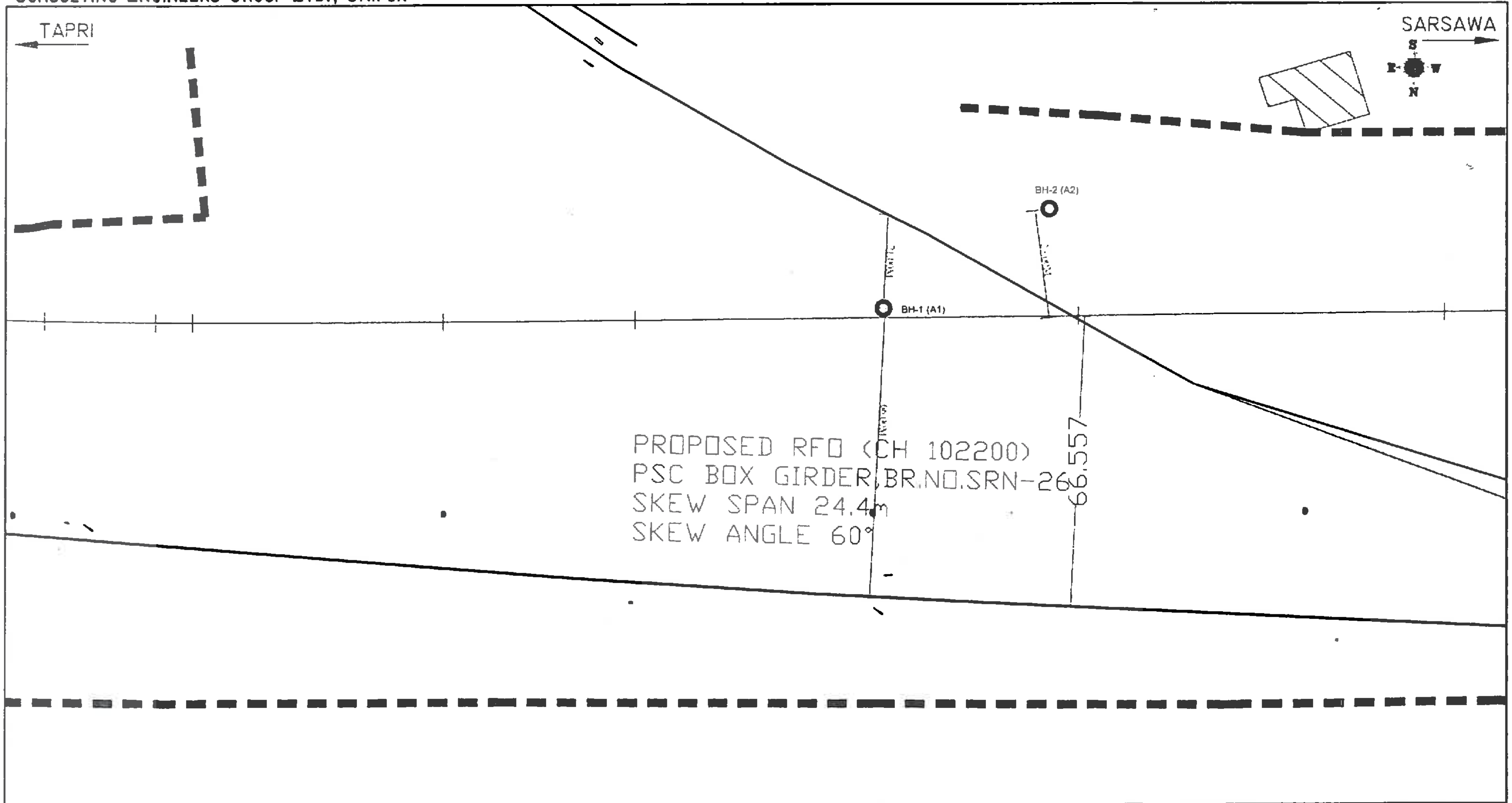
18.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

18.8 RECOMMENDATIONS

(i)	*Type of foundation*	Pile foundation

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED MAJOR BRIDGE
AT CH. 173/400

RL OF BH (A2) =269.973
RL OF BH (A2) = 266.978

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-
CONSULTING
ENGINEERS GROUP LTD.
E-12,Maji Colony,Malviya Nagar Jaipur-17
Tel: +91-141- 2520899, 2521899, 2520556
Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-A1 FOR RFO (ROR) AT CHAINAGE 173/400

Project :	Chainage 173/400 RFO (ROR) Bridge	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		29.12.2009 to 30.12.2009	A1	1	09.00 m.	30.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm²	ϕ degree
0.00	-	-	-	Silty Sand	0.00	7.39	62.35	30.26	0.00	0.00	0.00	24	NIL	NP	-	-	-	-	-	-
1.00	DS	-	-	Silty Sand	0.00	6.22	58.52	35.26	0.00	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
1.50	7	1.43	10.01	Silty Sand	0.00	9.55	58.57	31.88	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	0.00	5.87	88.08	6.05	0.00	0.00	0.00	29	NIL	NP	1.74	10.69	1.57	2.66	0.00	28.0
4.50	9	1.07	9.63	Silty Sand	2.68	8.20	80.6	8.52	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
7.50	13	0.90	11.70	Silty Sand	0.00	5.45	29.84	63.88	0.30	0.53	0.00	28	NIL	NP	-	-	-	-	-	-
9.00	UDS	-	-	Silty Sand	2.56	10.93	76.17	10.34	0.00	0.00	0.00	28	NIL	NP	1.85	16.59	1.59	2.65	0.00	29.0
10.50	16	0.78	12.48	Silty Sand	0.00	9.57	36.20	54.23	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
13.50	21	0.70	14.70	Silty Sand	0.00	8.37	32.56	58.42	0.65	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
16.50	28	0.63	16.32	Silty Sand	0.00	7.57	31.58	60.40	0.45	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
18.00	UDS	-	-	Silty Sand	0.00	9.90	75.92	14.18	0.00	0.00	0.00	24	NIL	NP	2.02	17.28	1.72	2.59	0.00	29.5
19.50	32	0.57	16.62	Silty Sand	0.00	8.49	75.26	16.25	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
22.50	39	0.52	17.64	Sand	0.00	3.82	25.60	69.99	0.50	0.09	0.00	31	NIL	NP	-	-	-	-	-	-
25.50	46	0.47	18.31	Sand	0.00	2.79	45.41	50.68	0.45	0.67	0.00	29	NIL	NP	-	-	-	-	-	-
28.50	54	0.43	19.11	Sand	0.00	2.74	40.36	55.62	0.66	0.62	0.00	26	NIL	NP	-	-	-	-	-	-
30.00	62	0.41	20.21	Sand	0.00	3.98	36.85	58.86	0.15	0.16	0.00	28	NIL	NP	-	-	-	-	-	-

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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-A2 FOR RFO (ROR) AT CHAINAGE 173/400

Project :	Chainage 173/400 RFO (ROR) Bridge	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		29.12.2009 to 29.12.2009	A2	2	09.60 m.	30.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Clay	Silt	Sand Fine	Sand Medium	Sand Coarse	Gravel Fine	Gravel Coarse	L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength c kg/cm^2	Shear Strength φ degree
0.00	-	-	-	Silty Sand	0.00	9.75	78.69	10.52	0.36	0.68	0.00	23	NIL	NP	-	-	-	-	-	-
1.20	DS	-	-	Silty Sand	3.69	14.61	72.39	8.35	0.48	0.48	0.00	25	NIL	NP	-	-	-	-	-	-
1.50	11	1.43	15.73	Silty Sand	4.26	13.22	74.92	6.80	0.56	0.24	0.00	27	NIL	NP	-	-	-	-	-	-
4.50	19	1.06	20.14	Silty Sand	0.00	9.69	47.90	38.66	1.15	2.60	0.00	28	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	3.41	28.26	63.08	4.49	0.76	0.00	0.00	24	NIL	NP	1.87	14.74	1.63	2.60	0.00	29.0
7.50	20	0.89	17.80	Silty Sand	3.25	10.96	24.59	60.35	0.85	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
10.50	24	0.78	16.86	Silty Sand	4.16	6.18	27.36	62.30	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Silty Sand	3.58	8.67	78.72	5.15	1.02	2.86	0.00	28	NIL	NP	1.90	16.43	1.63	2.65	0.00	29.5
13.50	29	0.69	17.51	Silty Sand	3.64	7.21	62.98	24.35	1.05	0.77	0.00	25	NIL	NP	-	-	-	-	-	-
16.50	35	0.62	18.35	Silty Sand	2.15	12.66	55.12	28.53	0.85	0.69	0.00	24	NIL	NP	-	-	-	-	-	-
19.50	42	0.57	19.47	Silty Sand	0.00	14.02	53.29	30.42	1.12	1.15	0.00	25	NIL	NP	-	-	-	-	-	-
21.00	UDS	-	-	Silty Sand	0.00	8.02	36.26	53.64	1.10	0.98	0.00	24	NIL	NP	2.00	18.66	1.68	2.67	0.00	28.5
22.50	53	0.52	21.28	Silty Sand	0.00	6.04	33.52	58.43	0.86	1.15	0.00	26	NIL	NP	-	-	-	-	-	-
25.50	58	0.47	21.13	Silty Sand	0.00	5.01	31.26	62.15	0.73	0.85	0.00	27	NIL	NP	-	-	-	-	-	-
28.50	66	0.43	21.69	Sand	0.00	3.70	30.22	64.35	0.60	1.13	0.00	26	NIL	NP	-	-	-	-	-	-
30.00	68	0.41	21.44	Sand	0.00	3.65	47.69	47.44	0.20	1.02	0.00	25	NIL	NP	-	-	-	-	-	-

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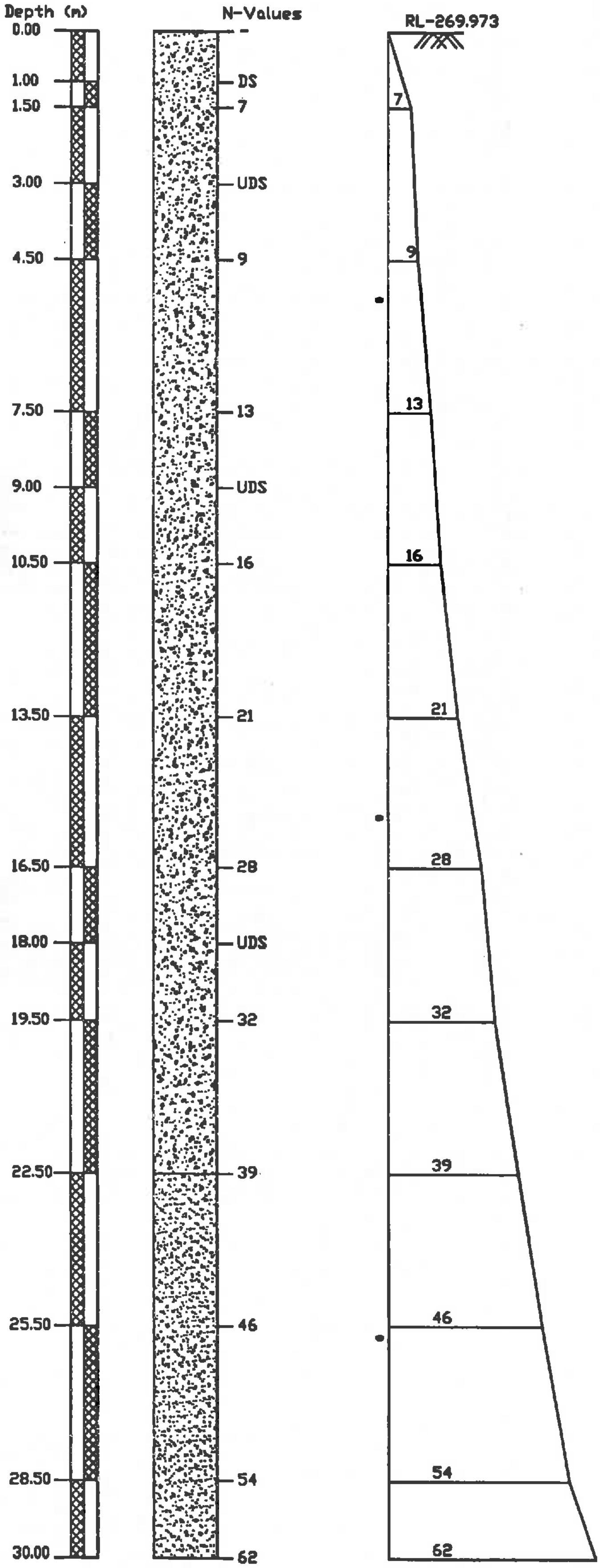
BORELOG OF BH-1(A1) AT EXISTING KM-173/400 FOR ROR,

ON KESARI TO SANEHWAL, LUDHIANA

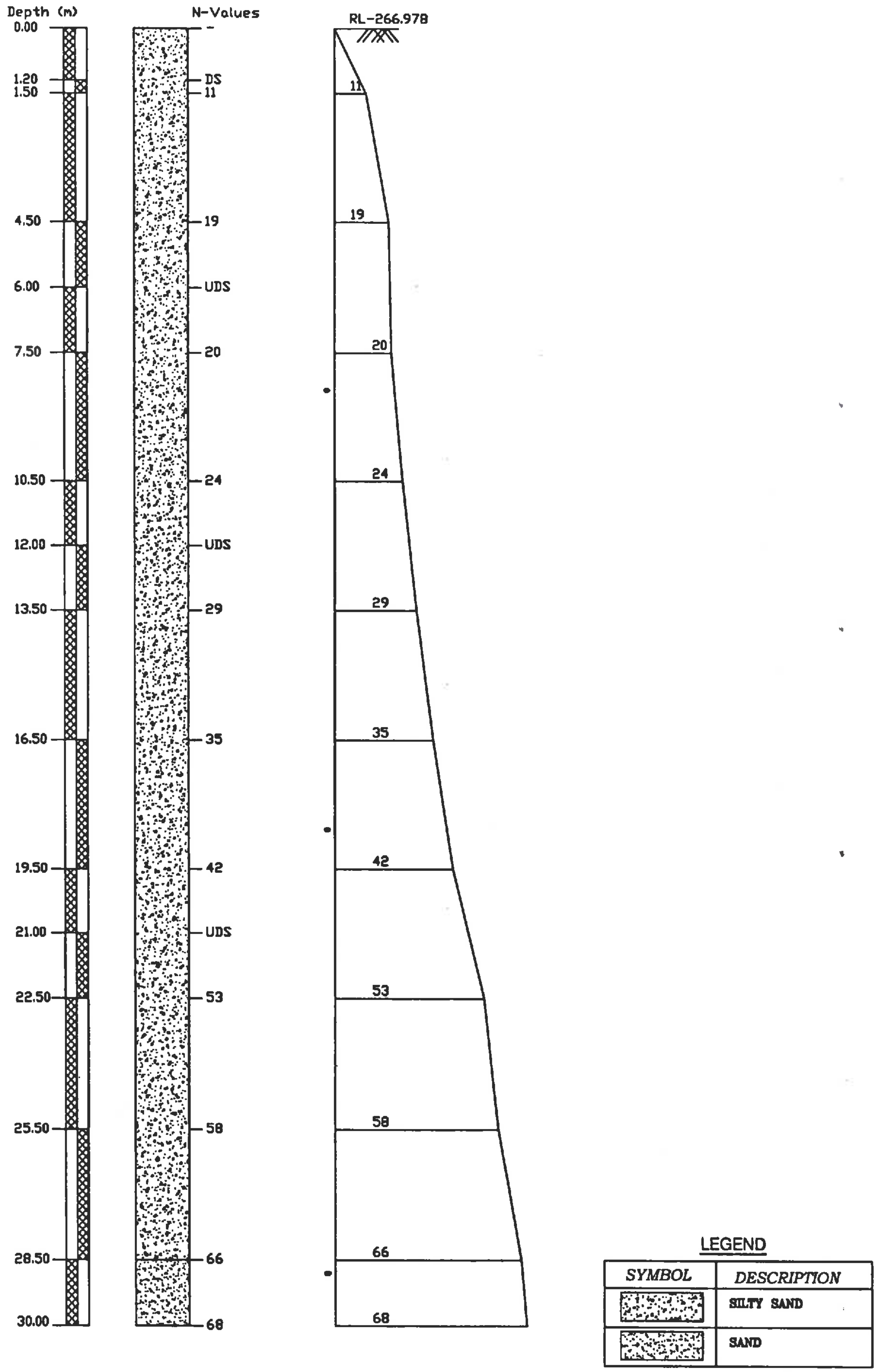


LEGEND

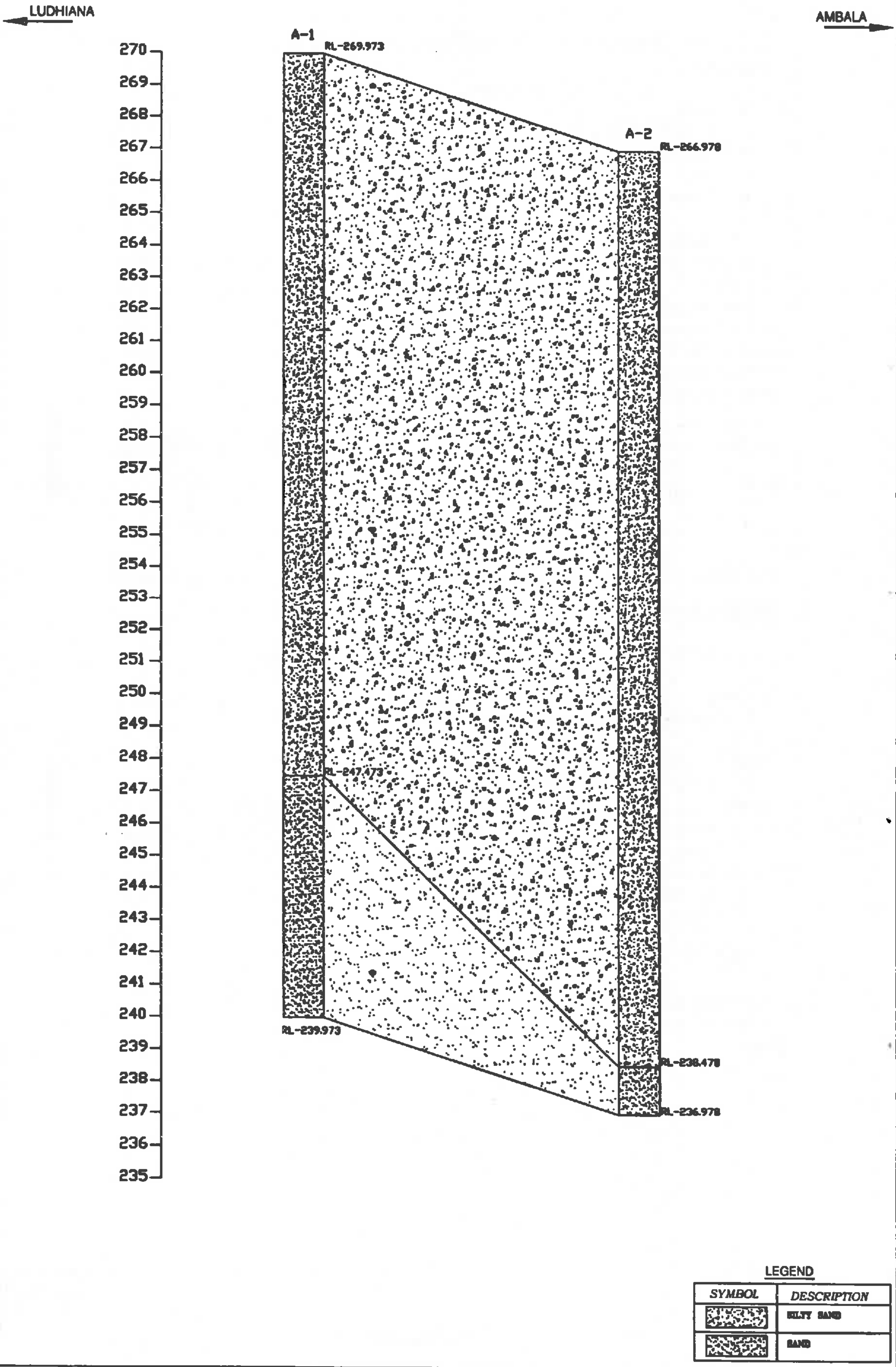
SYMBOL	DESCRIPTION
	SILTY SAND
	SAND

BORELOG OF BH–2(A2) AT EXISTING KM–173/400 FOR ROR,

ON KESARI TO SANEHWAL, LUDHIANA



BORE HOLE DETAIL AT ROR , CH.- 173/400



ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 173-400 BH-A1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.69
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.70
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

d_c = 1+ 0.2 (D_f/B)*SQRT(N_ϕ)

$d_q = d_\gamma = 1$ for ϕ <10°

$d_q = d_\gamma$ = 1 + 0.1 (D_f/B)*SQRT(N_ϕ) for ϕ >10°

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 tanϕ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.17	1.08	1.08
2	3.00	3.00	1.33	1.17	1.17
3	4.50	3.00	1.50	1.25	1.25
4	6.00	3.00	1.67	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	35.28	12.33	19.22
2	3.00	3.00	8.00	37.99	13.28	20.69
3	4.50	3.00	8.00	40.70	14.23	22.17
4	6.00	3.00	8.00	43.41	15.18	23.65

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 173 400 **BH-A2**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	27.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.83
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c\, s_c\, d_c\, i_c + q\,(N_q-1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c\, s_c\, d_c\, i_c + q\,(N'_q-1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

d_c = 1+ 0.2 (D_f/B)*SQRT(N_ϕ)

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma$ = 1 + 0.1 (D_f/B)*SQRT(N_ϕ) for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 tanϕ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.50
N_c	25.43
N_q	14.53
N_γ	16.64

ϕ'	19.23
N'_c	14.24
N'_q	6.02
N'_γ	4.97

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.25	1.25
4	6.00	3.00	1.66	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	33.77	12.02	17.46
2	3.00	3.00	8.00	36.34	12.94	18.79
3	4.50	3.00	8.00	38.91	13.85	20.12
4	6.00	3.00	8.00	41.48	14.77	21.44

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	ROR
Chainage	173/400
Bore Hole No.	A1

Footing Depth (m)	1.50
SBC (t/m2)	8.50
Average N value	10.00
Settlement for 10 t/m2 (mm)	32.00
Total Settlement (mm)	27.20
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	**24.8**

Footing Depth (m)	3.00
SBC (t/m2)	9.50
Average N value	10.00
Settlement for 10 t/m2 (mm)	32.00
Total Settlement (mm)	30.40
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	**25**

Footing Depth (m)	4.50
SBC (t/m2)	11.50
Average N value	11.00
Settlement for 10 t/m2 (mm)	29.00
Total Settlement (mm)	33.35
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	**24.3**

Footing Depth (m)	6.00
SBC (t/m2)	14.00
Average N value	12.00
Settlement for 10 t/m2 (mm)	26.00
Total Settlement (mm)	36.40
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	**24.8**

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	ROR
Chainage	173/400
Bore Hole No.	A2

Footing Depth (m)	1.50
SBC (t/m2)	15.00
Average N value	17.00
Settlement for 10 t/m2 (mm)	17.00
Total Settlement (mm)	25.50
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	23.2

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	19.00
Settlement for 10 t/m2 (mm)	14.00
Total Settlement (mm)	22.40
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	18.6

Footing Depth (m)	4.50
SBC (t/m2)	19.50
Average N value	19.00
Settlement for 10 t/m2 (mm)	14.00
Total Settlement (mm)	27.30
Depth Correction	0.78
Rigidity factor	0.8
Corrected Settlement (mm)	21.3

Footing Depth (m)	6.00
SBC (t/m2)	21.00
Average N value	19.00
Settlement for 10 t/m2 (mm)	14.00
Total Settlement (mm)	29.40
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	20.0

'ALIGNMENT'

CHAPTER - 17

"Major Bridge No. 210",

Location - Existing Km. - 172/03-04

CONSULTING Engineers Group Ltd.

17.1 LOCATION OF STRUCTURE:

Proposed Major Bridge of Span *4 x 30.50*

17.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *08.00m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1(A1)	0.00 to 4.50	Silty Sand	Loose
	4.50 to 19.50	Silty Sand	Medium Dense
	19.50 to 30.00	Silty Sand	Dense
BH-2(P2)	0.00 to 4.50	Silty Sand with Gravels	Loose
	4.50 to 16.50	Silty Sand	Medium Dense
	16.50 to 30.00	Silty Sand	Dense
BH-3(A2)	0.00 to 1.50	Silty Sand with Gravels	Loose
	1.50 to 16.50	Silty Sand	Medium Dense
	16.50 to 19.50	Sand	Medium Dense
	19.50 to 28.50	Sand	Dense
	28.50 to 30.00	Silty Sand	Dense

17.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1 (A1)	3.00	8.20	NIL	0.0014	NIL	0.0011	0.012
	12.00	8.40	NIL	0.0021	NIL	0.0012	0.088
	27.00	8.60	NIL	0.0022	NIL	0.0013	0.062
BH-2 (P2)	3.00	8.10	NIL	0.0024	NIL	0.0012	0.074
	9.00	9.70	0.010	0.0017	NIL	0.0012	0.053
	24.00	8.30	0.005	0.0021	NIL	0.0011	0.052
BH-3 (A2)	3.00	8.20	NIL	0.0025	NIL	0.0011	0.055
	12.00	8.60	0.005	0.0024	NIL	0.0011	0.058
	21.00	8.40	0.005	0.0020	NIL	0.0010	0.052

17.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1(A1)	3.00	NIL
	12.00	NIL
	27.00	NIL

BH-2(P2)	3.00	NIL
	9.00	NIL
	24.00	NIL
BH-3(A2)	3.00	NIL
	12.00	NIL
	21.00	NIL

17.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.40	49	NIL	75	356	0.6	2.20	458	715
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

17.6 PILE LOAD CARRYING CAPACITY

17.6.1 Normal Bored Cast in- situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC- 78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000.The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

<u>Safe bearing capacity in t/m²</u>

BH - NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m^2)
BH-1 (A1)	1.50	14.00
	3.00	15.00
	4.50	16.00
	6.00	17.00

BH-3 (A2)	1.50	16.00
	3.00	17.00
	4.50	18.50
	6.00	19.50

Pile load carrying capacity in t

BH -NO.	PILE DEPTH (mtr)	PILE CARRYING CAPACITY IN TONNE
		Pile Diameter= 1.2 m
BH-1 (A1)	17.00	220.00
	20.00	280.00
	23.00	345.00
BH-2 (P2)	17.00	220.00
	20.00	280.00
	23.00	345.00
BH-3 (A2)	17.00	220.00
	20.00	280.00
	23.00	345.00

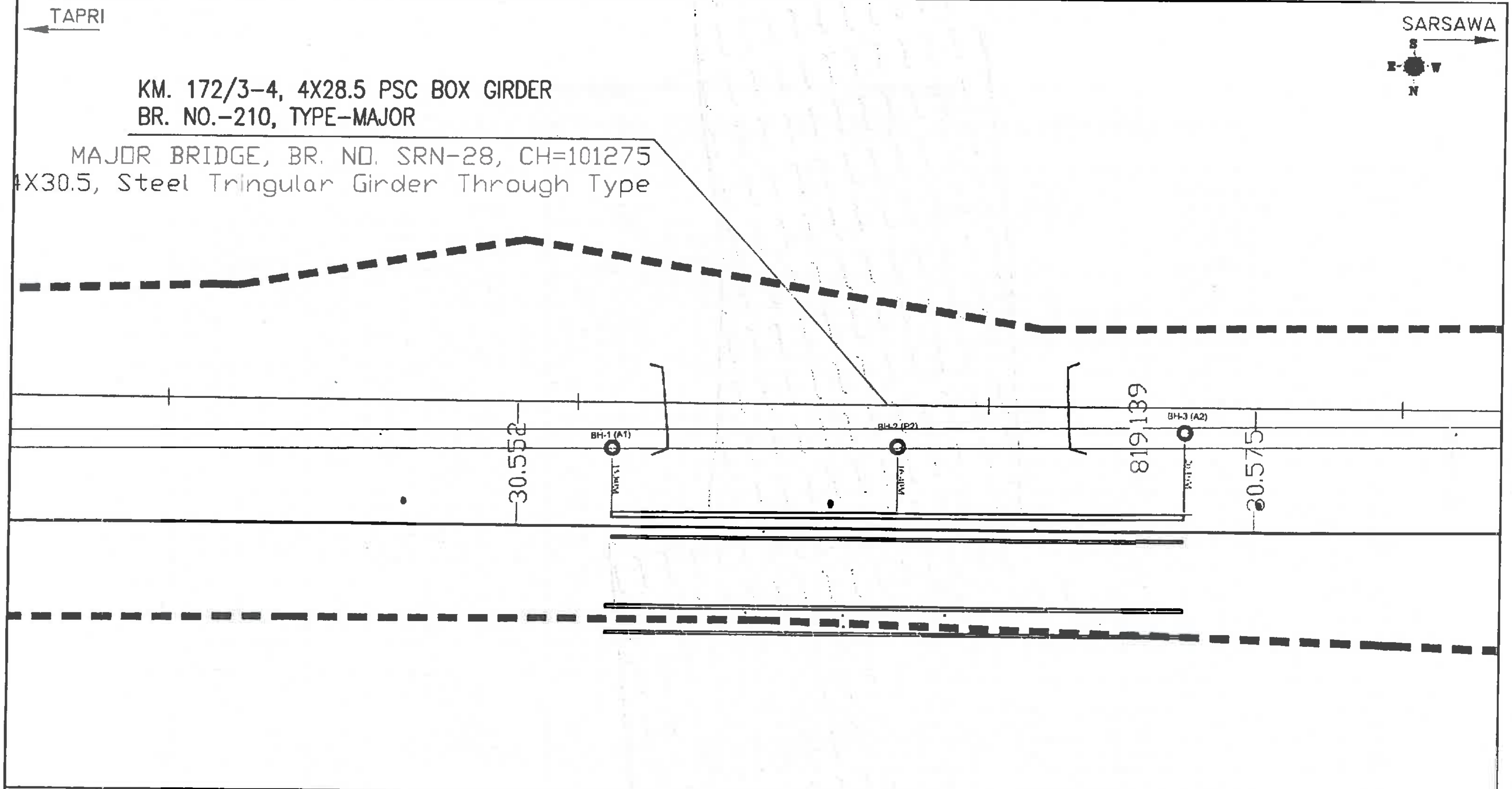
17.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

17.8 RECOMMENDATIONS

(i)	*Type of foundation*	Pile foundation

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED MAJOR BRIDGE AT CH. 172/03-05

RL OF BH I (AI) = 270.213
RL OF BH 2 (P2) = 264.163
RL OF BH 3 (A2) = 265.783

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-

CONSULTING ENGINEERS GROUP LTD.
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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE BH-A1 FOR MAJOR BRIDGE NO. 210 AT CHAINAGE 172/03-04

Project :	Chainage 172/03-04 Bridge No. 210	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		25.12.2009 to 26.12.2009	A1	1	08.00 m.	30.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm²	φ degree
0.00	-	-	-	Silty Sand	2.86	11.57	80.36	5.21	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
1.50	8	1.43	11.44	Silty Sand	3.14	10.31	83.46	3.09	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	0.00	8.99	84.55	6.46	0.00	0.00	0.00	28	NIL	NP	1.72	9.73	1.56	2.68	0.00	27.0
4.50	14	1.06	14.84	Silty Sand	0.00	9.43	77.93	12.61	0.03	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
7.50	17	0.89	15.13	Silty Sand	3.25	10.37	72.31	14.07	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
10.50	19	0.78	14.82	Silty Sand	0.00	5.71	33.82	60.47	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Silty Sand	0.00	5.97	36.26	57.45	0.32	0.00	0.00	26	NIL	NP	1.89	17.63	1.61	2.66	0.0	29.0
13.50	24	0.70	15.90	Silty Sand	0.00	5.79	38.97	55.13	0.11	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
16.50	29	0.63	16.64	Silty Sand	0.00	5.22	30.28	64.50	0.00	0.00	0.00	29	NIL	NP	-	-	-	-	-	-
19.50	33	0.57	16.91	Silty Sand	0.00	5.27	40.68	54.05	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
22.50	36	0.52	16.86	Silty Sand	0.00	6.67	50.48	42.85	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
25.50	40	0.48	17.10	Silty Sand	0.00	4.63	42.64	52.69	0.04	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
27.00	UDS	-	-	Silty Sand	0.00	10.81	16.38	72.69	0.12	0.00	0.00	25	NIL	NP	1.95	20.42	1.62	2.67	0.0	28.5
28.50	48	0.44	18.06	Silty Sand	0.00	5.68	15.87	78.45	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
30.00	57	0.42	19.47	Silty Sand	0.00	4.65	39.07	56.06	0.04	0.18	0.00	28	NIL	NP	-	-	-	-	-	-

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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-P2 FOR MAJOR BRIDGE NO. 210 AT CHAINAGE 172/03-04

Project :	Chainage 172/03-04 Bridge No. 210	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		27.12.2009 to 28.12.2009	P2	2	06.00 m.	30.00mtr	

Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm²	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Silty Sand with Gravels	3.68	31.86	42.32	11.52	2.36	8.26	0.00	25	NIL	NP	-	-	-	-	-	-
1.50	9	1.45	13.05	Silty Sand with Gravels	4.15	34.06	40.37	9.25	2.05	10.12	0.00	27	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand with Gravels	3.84	14.06	57.48	5.91	3.33	15.38	0.00	26	NIL	NP	1.77	10.41	1.60	2.64	0.00	29.5
4.50	13	1.08	14.04	Silty Sand	2.65	9.24	62.86	22.66	0.77	1.82	0.00	22	NIL	NP	-	-	-	-	-	-
7.50	18	0.91	15.69	Silty Sand	0.00	8.25	74.50	16.34	0.21	0.70	0.00	29	NIL	NP	-	-	-	-	-	-
9.00	UDS	-	-	Silty Sand	0.00	7.91	39.59	52.50	0.00	0.00	0.00	28	NIL	NP	1.86	16.69	1.59	2.72	0.0	28.5
10.50	23	0.79	16.59	Silty Sand	0.00	6.75	32.92	60.33	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
13.50	27	0.70	16.95	Silty Sand	0.00	7.70	43.23	49.07	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
16.50	30	0.63	16.95	Silty Sand	0.00	5.58	37.51	56.91	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
19.50	35	0.58	17.65	Silty Sand	0.00	6.20	64.35	29.38	0.07	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
22.50	38	0.53	17.57	Silty Sand	0.00	5.83	46.75	47.42	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
24.00	UDS	-	-	Silty Sand	0.00	7.55	24.70	67.75	0.00	0.00	0.00	28	NIL	NP	1.92	18.23	1.62	2.68	0.0	29.0
25.50	43	0.48	17.82	Silty Sand	0.00	5.96	28.36	65.68	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
28.50	49	0.45	18.53	Silty Sand	0.00	7.42	28.32	64.26	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
30.00	51	0.42	18.21	Silty Sand	0.00	9.24	28.32	59.89	0.84	1.71	0.00	26	NIL	NP	-	-	-	-	-	-

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SOIL CHARACTERISTICS OF BORE HOLE AT BH-A2 FOR MAJOR BRIDGE NO. 210 AT CHAINAGE 172/03-04

Project :	Chainage 172/03-04 Bridge No. 210	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		26.12.2009 to 27.12.2009	A2	3	08.00 m.	30.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand Fine	Sand Medium	Sand Coarse	Gravel Fine	Gravel Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength c kg/cm²	ϕ degree
0.00	-	-	-	Silty Sand with Gravels	0.00	7.74	77.39	8.62	0.00	6.25	0.00	25	NIL	NP	-	-	-	-	-	-
1.50	11	1.44	15.84	Silty Sand	0.00	9.98	83.78	6.24	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	2.59	10.41	78.48	8.52	0.00	0.00	0.00	26	NIL	NP	1.71	9.68	1.56	2.67	0.00	27.5
4.50	17	1.07	18.19	Silty Sand	3.25	10.05	80.35	6.35	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
7.50	21	0.90	18.90	Silty Sand	2.48	10.55	81.57	5.40	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
10.50	23	0.79	16.59	Silty Sand	0.00	5.24	47.55	47.21	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Silty Sand	3.64	12.48	79.53	4.35	0.00	0.00	0.00	24	NIL	NP	2.00	15.66	1.73	2.64	0.00	29.0
13.50	27	0.69	16.82	Silty Sand	0.00	6.77	47.81	45.42	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
16.50	29	0.62	16.49	Sand	0.00	4.95	48.40	46.65	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
19.50	34	0.56	17.02	Sand	0.00	4.03	38.25	57.72	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
21.00	UDS	-	-	Sand	0.00	4.16	35.42	60.42	0.00	0.00	0.00	25	NIL	NP	2.03	18.36	1.72	2.66	0.00	29.0
22.50	38	0.51	17.19	Sand	0.00	4.38	33.02	62.60	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
25.50	43	0.47	17.61	Sand	0.00	5.28	61.70	32.95	0.07	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
28.50	48	0.43	17.82	Silty Sand	0.00	6.64	42.66	50.65	0.05	0.00	0.00	29	NIL	NP	-	-	-	-	-	-
30.00	59	0.41	19.60	Silty Sand	0.00	5.73	38.99	55.28	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-

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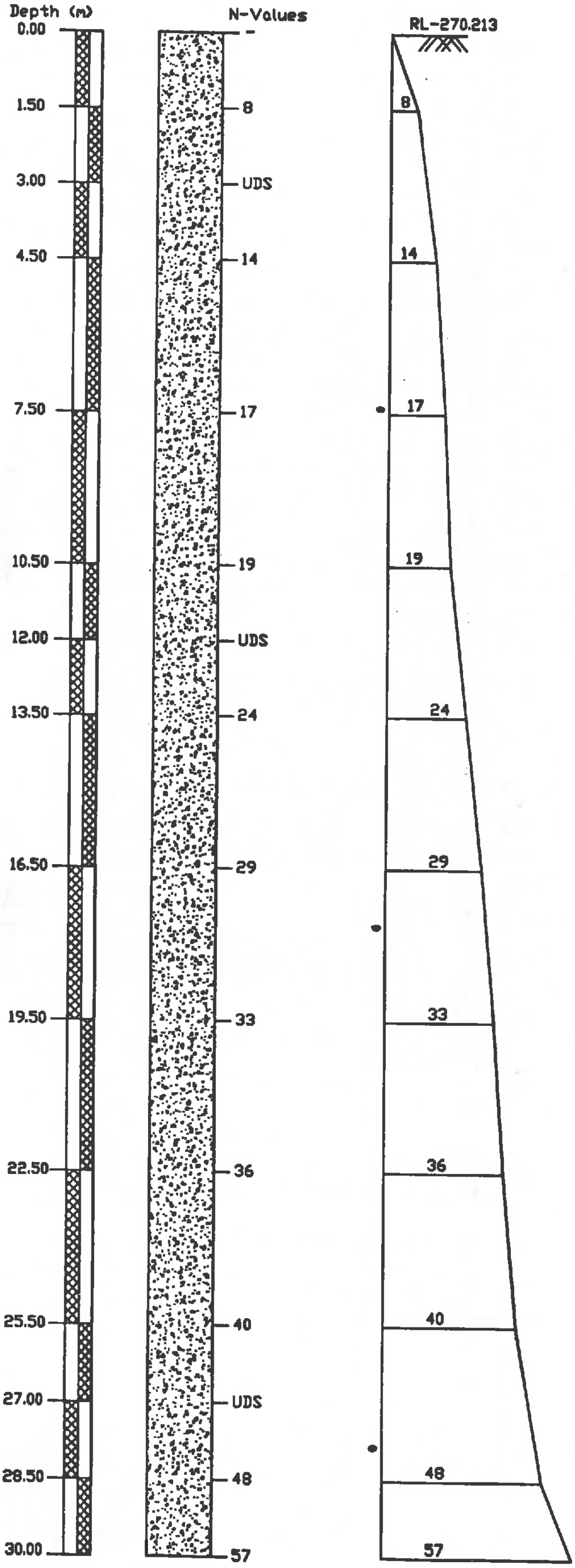
ANNEXURE-II

BORELOG OF BH-1(A1) AT EXISTING KM-172/03-05 FOR MAJOR BRIDGE NO.-210, ON KESARI TO SANEHWAL, LUDHIANA

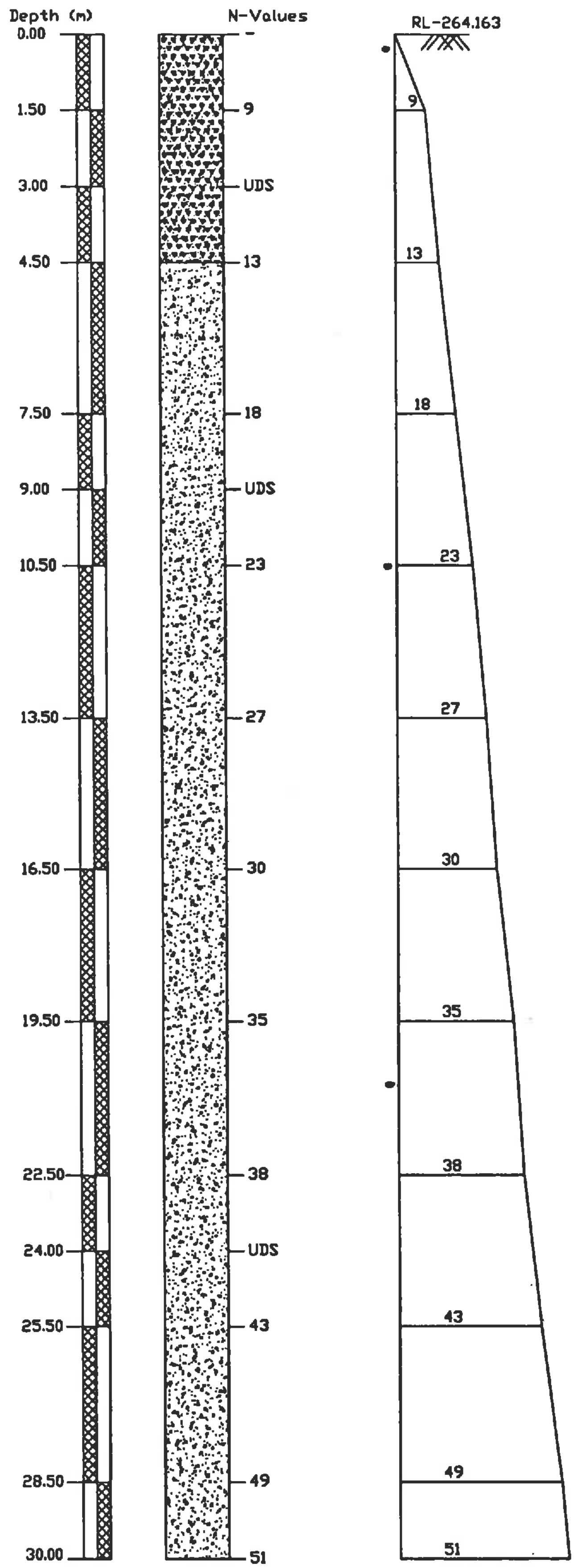


LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND

ANNEXURE-II

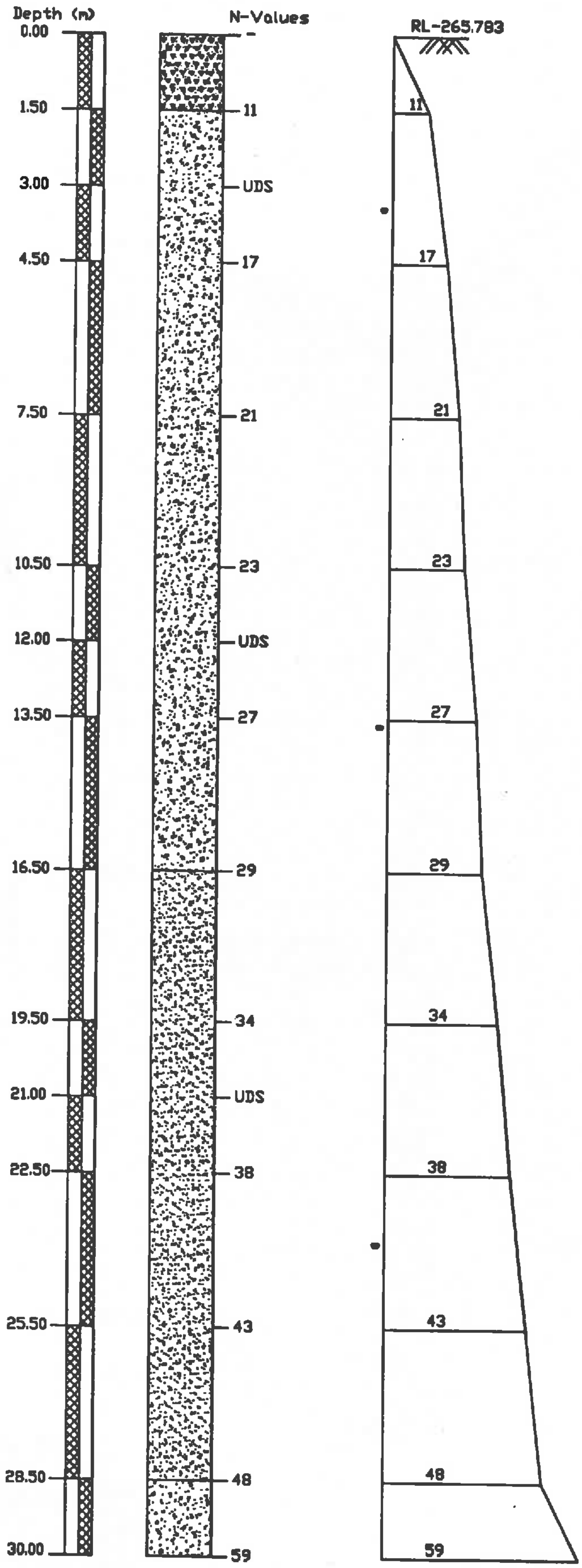
BORELOG OF BH–2(P2) AT EXISTING KM–172/03–05 FOR MAJOR BRIDGE NO.–210, ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
(cross-hatched)	SILTY SAND WITH GRAVELS
(dotted)	SILTY SAND

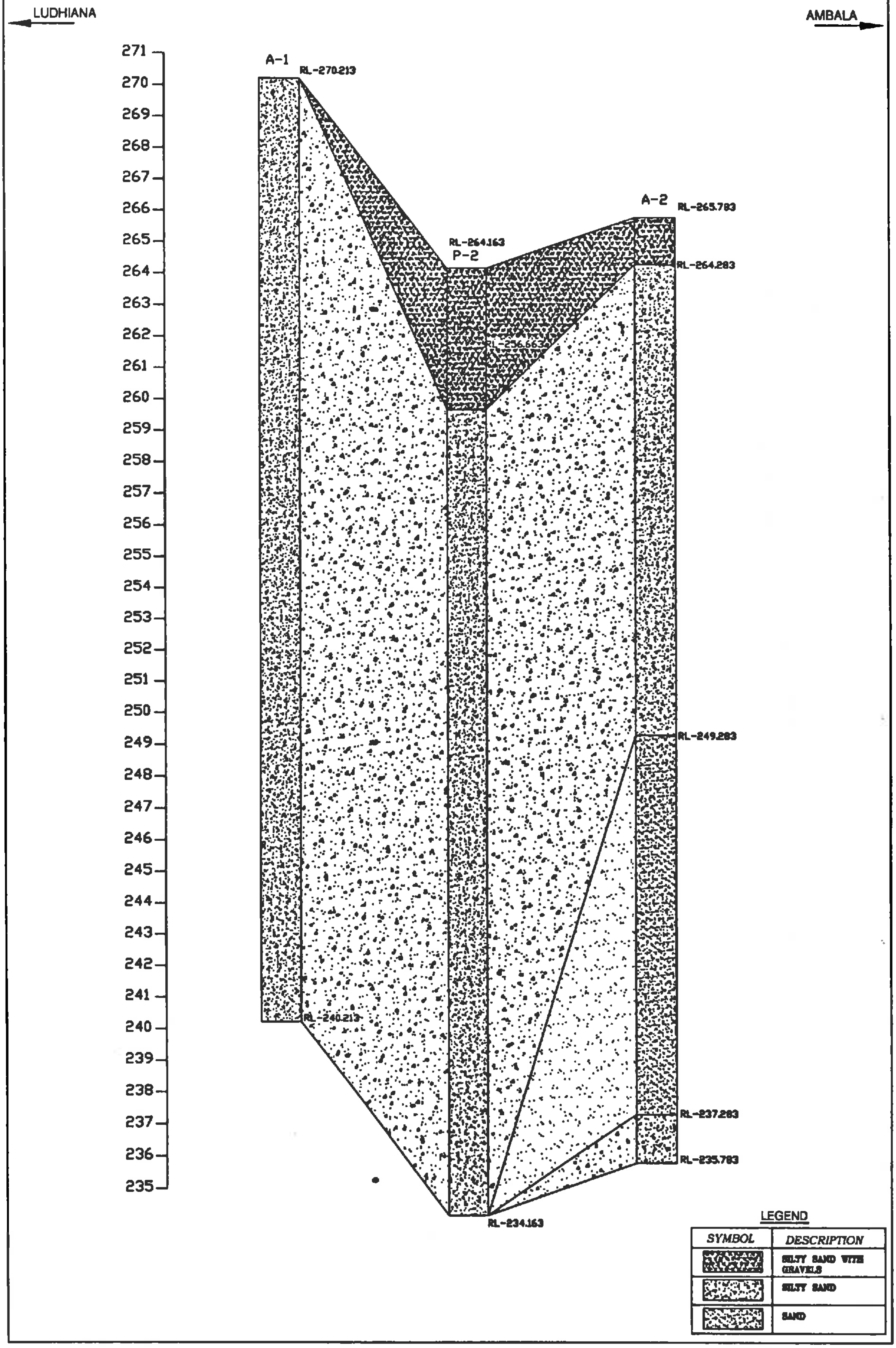
BORELOG OF BH-3(A2) AT EXISTING KM-172/03-05 FOR MAJOR BRIDGE NO.-210,
ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND WITH GRAVELS
	SILTY SAND
	SAND

BORE HOLE DETAIL AT MAJOR BRIDGE NO. 210 CH.- 172/03-05



ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 172 3-5 **BH-A1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.72
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.70
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c\, s_c d_c i_c + q\,(N_q-1)\, s_q d_q i_q + (1/2)\, B\, \gamma N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c s_c d_c i_c + q\,(N'_q-1)\, s_q d_q i_q + (1/2)\, B\, \gamma N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1+ 0.2\,(D_f/B)^*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)^*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	31.27	11.41	14.39
2	3.00	3.00	8.00	33.62	12.27	15.48
3	4.50	3.00	8.00	35.98	13.14	16.56
4	6.00	3.00	8.00	38.34	14.00	17.65

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

	Ch 172 3-5	**BH-A2**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular	**2**

Angle of internal friction (ϕ °)	27.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.71
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.70
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

ANNEXURE - III

Bearing capacity factors :

ϕ	27.50
N_c	25.43
N_q	14.53
N_γ	16.64

ϕ'	19.23
N'_c	14.24
N'_q	6.02
N'_γ	4.97

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.25	1.25
4	6.00	3.00	1.66	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	33.27	11.87	16.15
2	3.00	3.00	8.00	35.80	12.78	17.38
3	4.50	3.00	8.00	38.34	13.68	18.61
4	6.00	3.00	8.00	40.87	14.58	19.84

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Major Bridge
Chainage	172/03-05
Bore Hole No.	A1

Footing Depth (m)	1.50
SBC (t/m2)	14.00
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	33.60
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	24.5

Footing Depth (m)	3.00
SBC (t/m2)	15.00
Average N value	14.00
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	31.50
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	20.9

Footing Depth (m)	4.50
SBC (t/m2)	16.00
Average N value	15.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	28.80
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	16.8

Footing Depth (m)	6.00
SBC (t/m2)	17.00
Average N value	15.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	30.60
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	16.6

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Major Bridge
Chainage	172/03-05
Bore Hole No.	A2

Footing Depth (m)	1.50
SBC (t/m2)	16.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	17.00
Total Settlement (mm)	27.20
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	19.8

Footing Depth (m)	3.00
SBC (t/m2)	17.00
Average N value	18.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	25.50
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	16.9

Footing Depth (m)	4.50
SBC (t/m2)	18.50
Average N value	18.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	27.75
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	16.2

Footing Depth (m)	6.00
SBC (t/m2)	19.50
Average N value	18.00
Settlement for 10 t/m2 (mm)	15.00
Total Settlement (mm)	29.25
Depth Correction	0.67
Rigidity factor	0.8
Corrected Settlement (mm)	15.7

CHAPTER - 16

"Major Bridge No. 219",

Location - Existing Km. - 179/31-37

CONSULTING Engineers Group Ltd.

16.1 LOCATION OF STRUCTURE:
Proposed Major Bridge of Span *3 x 24.40*

16.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in FIGURE-1.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *07.0m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1(A1)	0.00 to 1.50	Filled up Strata	Loose
	1.50 to 3.00	Silty Sand with Gravels	Medium Dense
	3.00 to 12.00	Silty Sand	Medium Dense
	12.00 to 13.50	Sandy Silt with Clay	Medium Dense
	13.50 to 16.50	Silty Sand	Medium Dense
	16.50 to 30.00	Silty Sand	Dense
BH-2(P1)	0.00 to 1.50	Filled up Strata	Loose
	1.50 to 7.50	Silty Sand	Loose
	7.50 to 22.50	Silty Sand	Medium Dense
	22.50 to 24.00	Silty Sand	Medium Dense
	24.00 to 25.50	Silty Sand with Gravels	Dense
	25.50 to 30.00	Silty Sand	Dense
BH-3(A2)	0.00 to 3.00	Filled up Strata	Loose
	3.00 to 4.50	Sand	Loose
	4.50 to 12.00	Sand	Medium Dense
	12.00 to 16.50	Silty Sand	Medium Dense
	16.50 to 30.00	Silty Sand	Dense

16.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1 (A1)	3.00	8.70	0.005	0.0025	NIL	0.0011	0.0033
	12.00	8.50	0.002	0.0021	NIL	0.0011	0.028
	27.00	8.60	NIL	0.0022	NIL	0.0013	0.0041
BH-2 (P1)	3.00	8.10	NIL	0.0014	NIL	0.0011	0.043
	9.00	7.90	NIL	0.0024	NIL	0.0012	0.059
	24.00	8.20	NIL	0.0024	NIL	0.0012	0.051
BH-3 (A2)	12.00	8.40	NIL	0.0017	NIL	0.0011	0.030

	21.00	8.50	NIL	0.0021	NIL	0.0012	0.0033

16.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1(A1)	3.00	NIL
	12.00	NIL
	27.00	NIL
BH-2 (P1)	3.00	NIL
	9.00	NIL
	24.00	NIL
BH-3 (A2)	12.00	NIL
	21.00	NIL

16.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.0	138	110	153	710	0.3	2.8	870	1349
Requirement as per IS:456 / Mosrth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

16.6 PILE LOAD CARRYING CAPACITY

16.6.1 Normal Bored Cast in- situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC- 78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein.. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000.The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

Safe bearing capacity in t/m²

BH - NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m²)
BH-1 (A1)	1.50	15.00
	3.00	16.00
	4.50	18.00
	6.00	19.00
BH-3 (A2)	3.00	11.00
	4.50	12.00
	6.00	12.50

Pile load carrying capacity in t

BH -NO.	PILE DEPTH (mtr)	PILE CARRYING CAPACITY IN TONNE
		Pile Diameter= 1.20 m
BH-1 (A1)	17.00	215.00
	20.00	275.00
	23.00	340.00
BH-2 (P1)	17.00	190.00
	20.00	240.00
	23.00	300.00
BH-3 (A2)	17.00	190.00
	20.00	240.00
	23.00	300.00

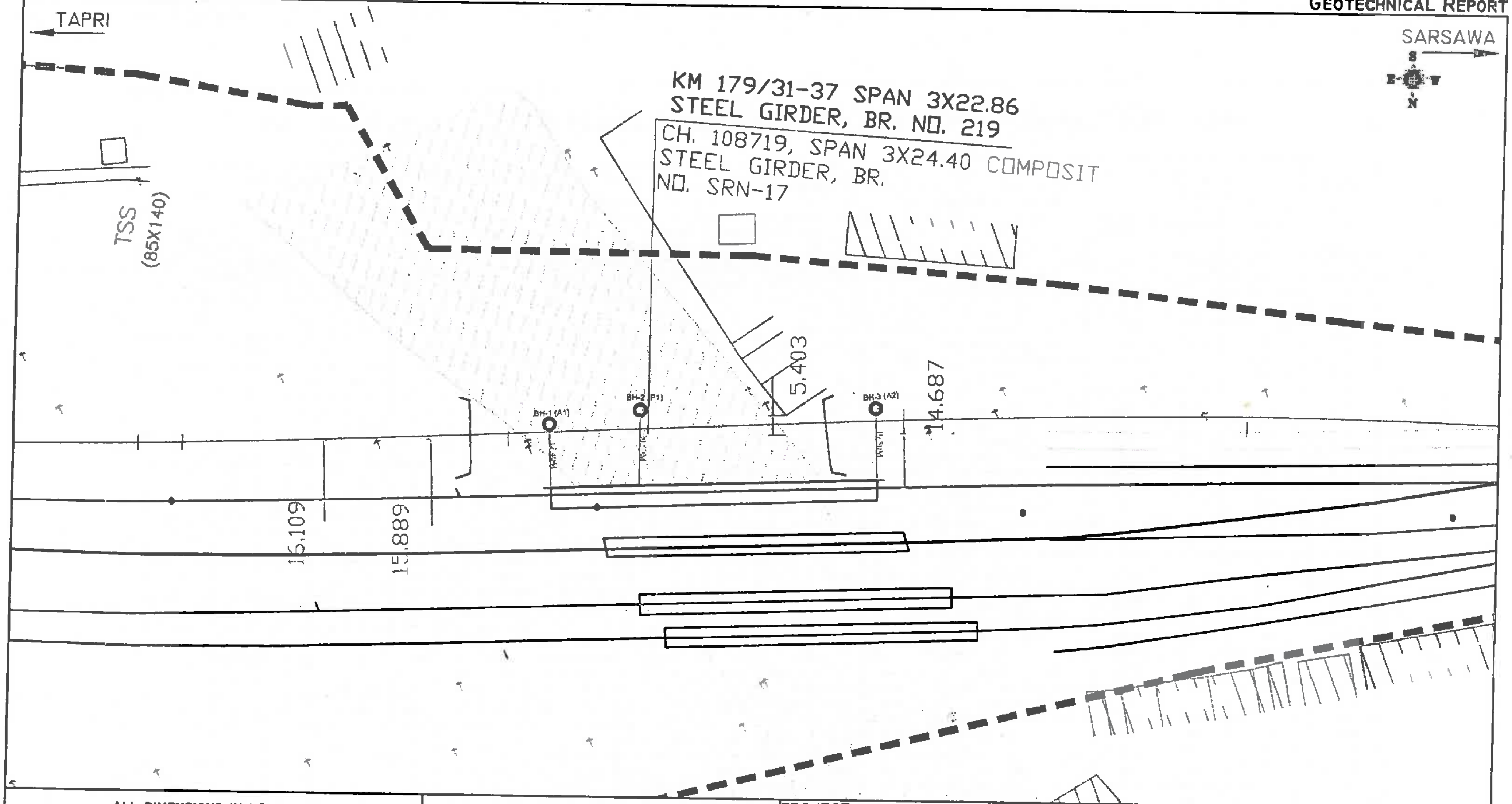
16.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

16.8 RECOMMENDATIONS

(i)	*Type of foundation*	Pile foundation

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I

LOCATION PLAN OF PROPOSED MAJOR BRIDGE AT CH. 179/31/37

RL OF BH (AI) =270.743
RL OF BH (PI) =265.953
RL OF BH (A2) =273.853

PROJECT :-

LUDHIANA-AMBALA (DFCCIL)

DESIGN :-

CONSULTING ENGINEERS GROUP LTD.
E-12,Moji Colony,Malviya Nagar Jaipur-17
Tel: +91-141- 2520899, 2521899, 2520556
Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE BH-A1 FOR MAJOR BRIDGE NO. 219 AT CHAINAGE 179/31-37

Project :	Chainage 179/31-37 Bridge No. 219			Date of Testing	Location at		B.H. No.			Depth of Water Table		Termination Depth			Surface Elevation					
				22.12.2009 to 23.12.2009	A1		1			07.00 m.		30.00mtr								
Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Filled up Strata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.50	12	1.43	17.16	Silty Sand with Gravels	0.00	9.41	35.37	45.71	1.86	7.65	0.00	27	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	3.62	18.10	59.06	18.94	0.15	0.13	0.00	25	NIL	NP	1.74	8.85	1.59	2.70	0.00	26.5
4.50	15	1.06	15.90	Silty Sand	2.85	15.40	60.52	20.62	0.35	0.26	0.00	24	NIL	NP	-	-	-	-	-	-
7.50	19	0.89	15.96	Silty Sand	4.35	5.23	58.07	32.12	0.23	0.00	0.00	29	NIL	NP	-	-	-	-	-	-
10.50	24	0.78	16.86	Silty Sand	3.76	6.76	34.26	54.31	0.21	0.70	0.00	26	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Sandy Silt with Clay	9.26	69.11	14.45	4.57	0.75	1.86	0.00	26	18	8	1.95	18.38	1.65	2.67	0.09	21.0
13.50	28	0.69	17.16	Silty Sand	2.86	20.35	52.82	22.04	1.18	0.75	0.00	23	NIL	NP	-	-	-	-	-	-
16.50	31	0.62	17.11	Silty Sand	3.52	8.20	60.45	26.08	0.11	1.64	0.00	24	NIL	NP	-	-	-	-	-	-
19.50	34	0.56	17.02	Silty Sand	4.12	9.88	48.66	35.08	1.26	1.00	0.00	24	NIL	NP	-	-	-	-	-	-
22.50	39	0.52	17.64	Silty Sand	3.49	11.51	57.19	27.71	0.10	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
25.50	44	0.47	17.84	Silty Sand	3.69	10.09	44.75	40.85	0.37	0.25	0.00	24	NIL	NP	-	-	-	-	-	-
27.00	UDS	-	-	Silty Sand	2.68	13.29	50.26	32.26	1.15	0.36	0.00	23	NIL	NP	2.07	18.16	1.75	2.67	0.00	30.0
28.50	47	0.43	17.61	Silty Sand	3.15	8.82	58.54	29.22	0.27	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
30.00	52	0.40	17.90	Silty Sand	2.36	12.99	47.05	32.44	1.44	3.72	0.00	23	NIL	NP	-	-	-	-	-	-

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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE BH-P1 FOR MAJOR BRIDGE NO. 219 AT CHAINAGE 179/31-37

Project :	Chainage 179/31-37 Bridge No. 219	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		23.12.2009 to 24.12.2009	P1	2	07.00 m.	30.00mtr	

Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	φ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Filled up Strata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1.50	9	1.44	12.96	Silty Sand	3.15	7.92	59.90	28.03	0.39	0.61	0.00	26	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	3.68	10.88	32.29	51.28	0.78	1.09	0.00	26	NIL	NP	1.79	12.11	1.60	2.70	0.00	29.0
4.50	8	1.07	8.56	Silty Sand	2.85	9.40	45.62	40.26	0.65	1.22	0.00	24	NIL	NP	-	-	-	-	-	-
7.50	16	0.90	14.40	Silty Sand	3.98	10.24	47.43	36.37	0.33	1.65	0.00	25	NIL	NP	-	-	-	-	-	-
9.00	UDS	-	-	Silty Sand	0.00	3.11	85.85	6.09	0.00	4.95	0.00	29	NIL	NP	1.91	17.85	1.62	2.70	0.00	28.0
10.50	19	0.78	14.82	Silty Sand	3.26	7.85	43.06	45.76	0.07	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
13.50	22	0.70	15.20	Silty Sand	4.69	39.82	53.91	0.88	0.24	0.46	0.00	31	NIL	NP	-	-	-	-	-	-
16.50	25	0.63	15.38	Silty Sand	3.84	10.66	61.02	24.16	0.32	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
19.50	27	0.57	15.20	Silty Sand	3.26	11.52	51.32	33.50	0.40	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
22.50	31	0.52	15.56	Silty Sand	3.75	7.57	56.21	30.53	0.70	1.24	0.00	25	NIL	NP	-	-	-	-	-	-
24.00	UDS	-	-	Silty Sand with Gravels	3.85	5.85	53.36	23.01	0.35	7.68	5.90	29	NIL	NP	1.94	20.40	1.61	2.69	0.00	28.5
25.50	37	0.48	16.38	Silty Sand	3.14	6.10	55.98	34.55	0.09	0.14	0.00	24	NIL	NP	-	-	-	-	-	-
28.50	43	0.44	16.96	Silty Sand	3.75	8.84	34.61	49.00	1.60	2.20	0.00	26	NIL	NP	-	-	-	-	-	-
30.00	46	0.42	17.16	Silty Sand	4.16	7.10	50.47	33.78	0.28	4.21	0.00	26	NIL	NP	-	-	-	-	-	-

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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE BH-A2 FOR MAJOR BRIDGE NO. 219 AT CHAINAGE 179/31-37

Project :	Chainage 179/31-37 Bridge No. 219	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		24.12.2009 to 25.12.2009	A2	3	16.00 m.	30.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm²	ϕ degree
0.00	-	-	-	Filled up Strata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.00	DS	-	-	Sand	3.68	2.28	26.65	67.33	0.06	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
4.50	17	1.09	18.53	Sand	4.00	3.80	32.14	60.06	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
7.50	21	0.92	19.32	Sand	3.89	3.70	26.44	65.97	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
10.50	24	0.81	19.44	Sand	3.82	2.09	11.06	83.03	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Silty Sand	3.68	23.90	68.23	4.19	0.00	0.00	0.00	26	NIL	NP	1.85	13.01	1.63	2.65	0.00	29.0
13.50	28	0.72	20.16	Silty Sand	2.86	8.35	48.28	40.51	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
16.50	30	0.66	17.40	Silty Sand	3.78	6.86	60.54	28.58	0.15	0.09	0.00	27	NIL	NP	-	-	-	-	-	-
19.50	33	0.60	17.40	Silty Sand	3.68	6.53	62.00	27.68	0.11	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
21.00	UDS	-	-	Silty Sand	2.95	9.01	60.84	26.84	0.36	0.00	0.00	25	NIL	NP	1.86	15.36	1.61	2.67	0.00	28.0
22.50	35	0.55	17.13	Silty Sand	4.21	7.36	59.25	28.97	0.21	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
25.50	38	0.50	17.00	Silty Sand	3.68	5.77	42.41	47.97	0.17	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
28.50	43	0.46	17.39	Silty Sand	3.52	8.32	54.49	33.38	0.12	0.17	0.00	27	NIL	NP	-	-	-	-	-	-
30.00	48	0.44	18.06	Silty Sand	3.62	40.84	12.10	43.07	0.37	0.00	0.00	26	NIL	NP	-	-	-	-	-	-

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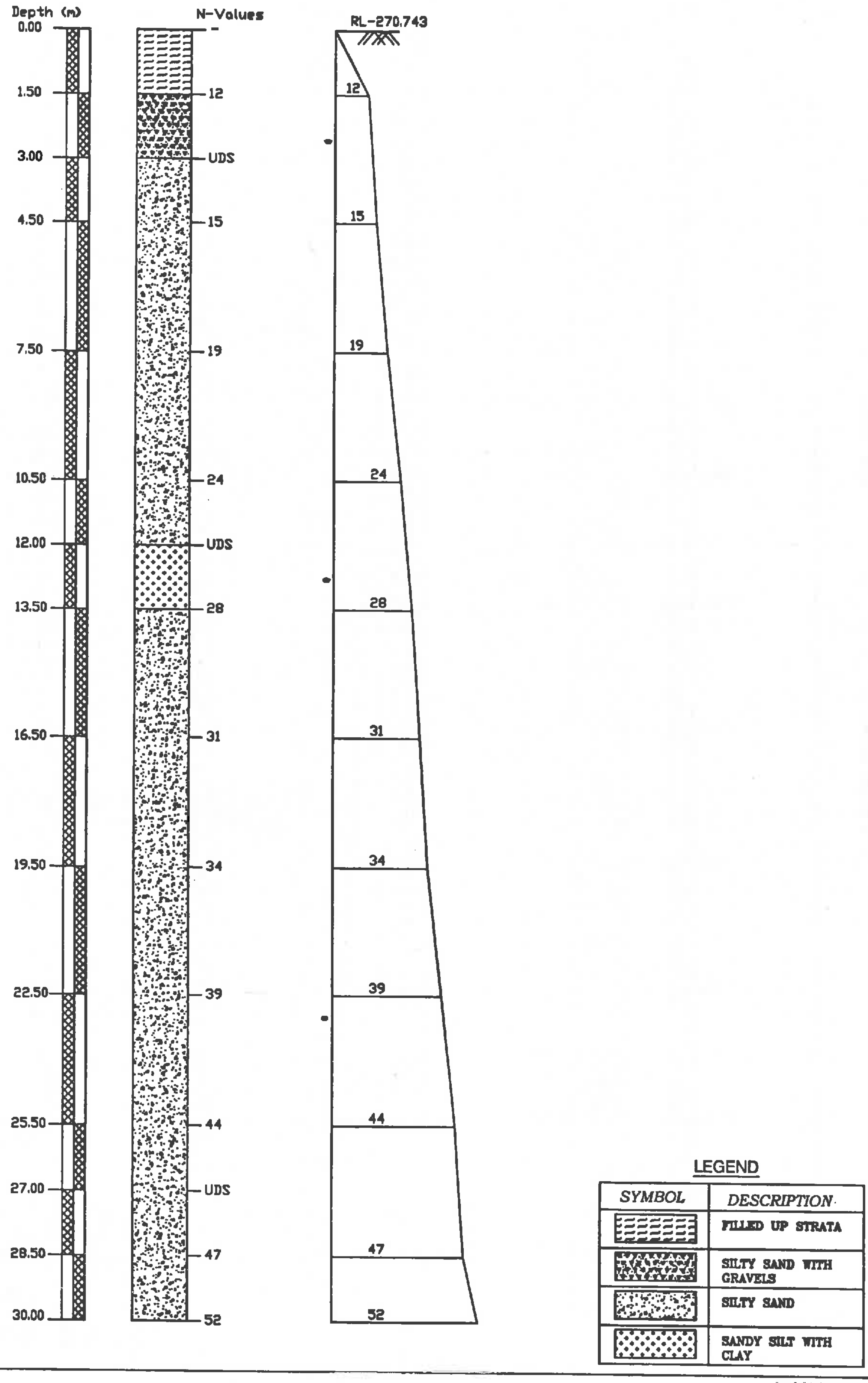
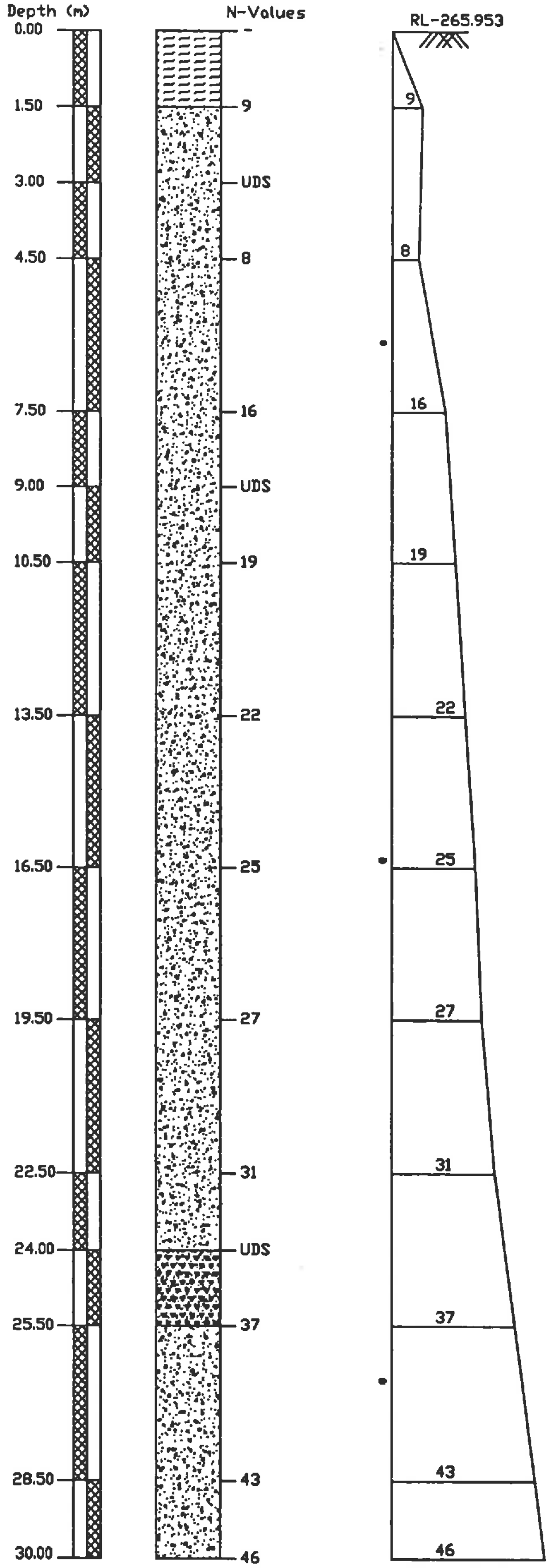
BORELOG OF BH-1(A1) AT EXISTING KM-179/31-37 FOR MAJOR BRIDGE NO.-219, ON KESARI TO SANEHWAL, LUDHIANA



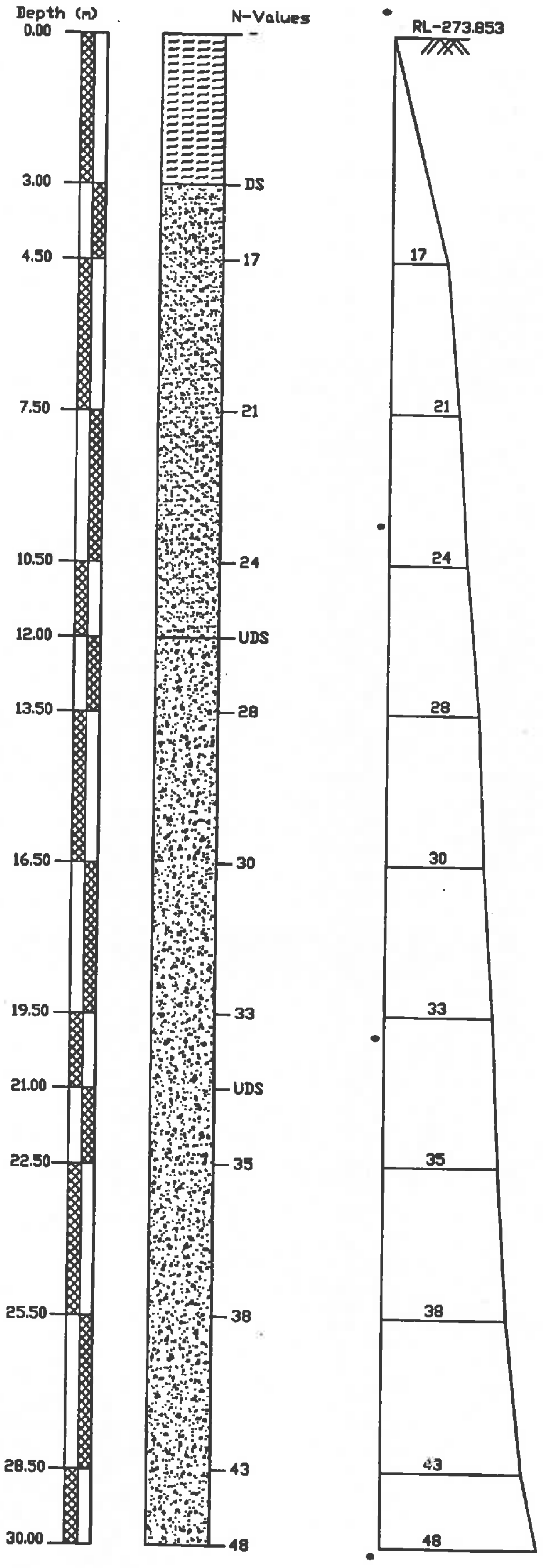
BORELOG OF BH–2(P1) AT EXISTING KM–179/31–37 FOR MAJOR BRIDGE NO.–219, ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	FILLED UP STRATA
	SILTY SAND
	SILTY SAND WITH GRAVELS

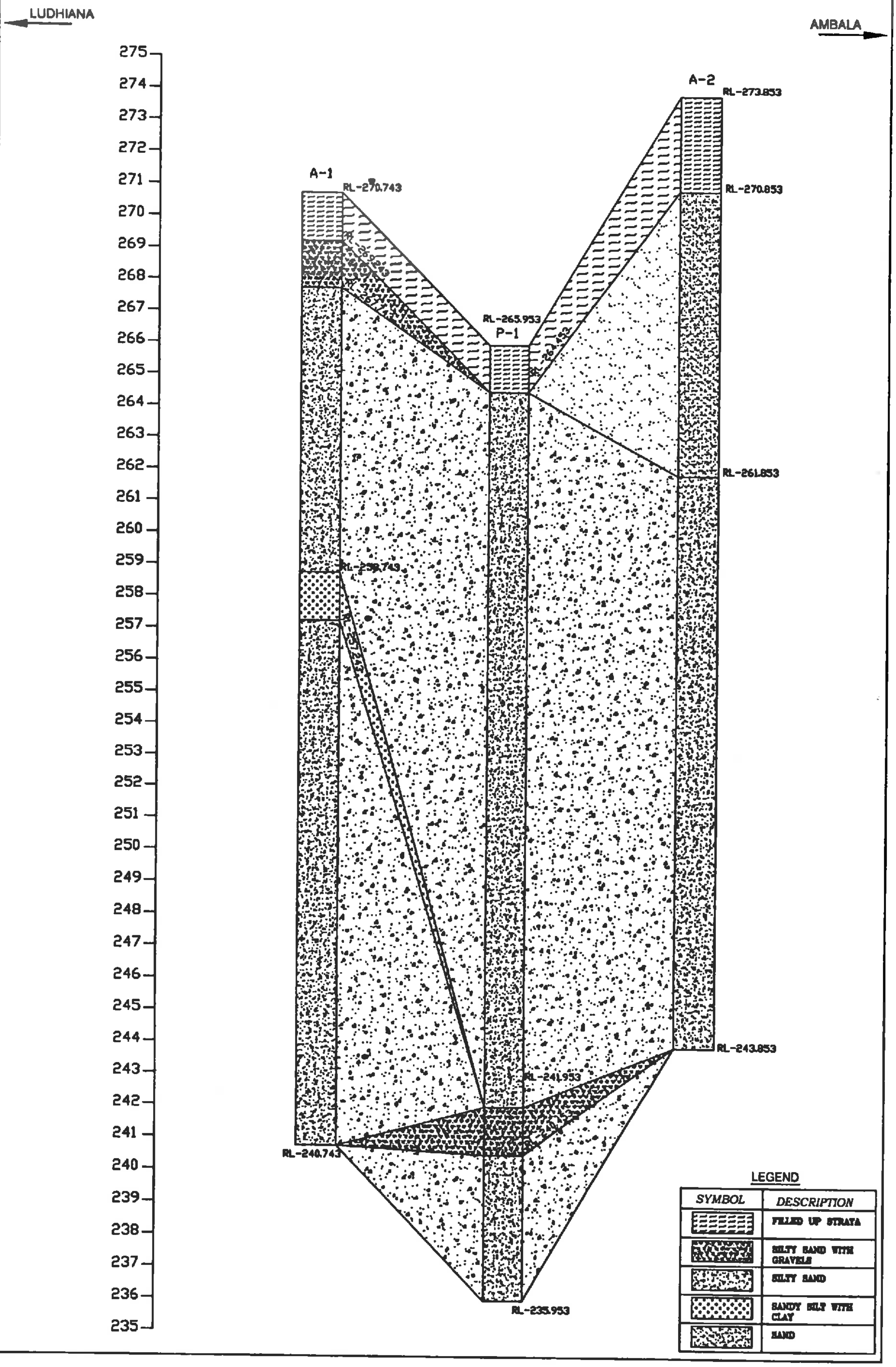
BORELOG OF BH-3(A2) AT EXISTING KM-179/31-37 FOR MAJOR BRIDGE NO.-219, ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	FILLED UP STRATA
	SAND
	SILTY SAND

BORE HOLE DETAIL AT MAJOR BRIDGE NO. 219, CH.- 179/31-37



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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 179 31-37 BH-A1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular 2

Angle of internal friction (ϕ °)	26.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.74
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*\mathrm{SQRT}(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*\mathrm{SQRT}(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	26.50
N_c	23.55
N_q	12.98
N_γ	14.34

ϕ'	18.47
N'_c	13.65
N'_q	5.65
N'_γ	4.55

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.32	1.16	1.16
3	4.50	3.00	1.48	1.24	1.24
4	6.00	3.00	1.65	1.32	1.32

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	29.40	11.00	15.60
2	3.00	3.00	8.00	31.59	11.82	16.77
3	4.50	3.00	8.00	33.79	12.64	17.93
4	6.00	3.00	8.00	35.99	13.47	19.10

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 179 31-37 BH-A2

Type of footing

1. Continuous Strip
2. Rectangular
3. Square
4. Circular

Rectangular 2

Angle of internal friction (ϕ °)	26.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.75
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.70
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	3.00	3.00	8.00
2	4.50	3.00	8.00
3	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q - 1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q - 1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)^*\mathrm{SQRT}(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)^*\mathrm{SQRT}(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

ANNEXURE - III

Bearing capacity factors :

ϕ	26.00
N_c	22.60
N_q	12.21
N_γ	13.18

ϕ'	18.10
N'_c	13.36
N'_q	5.46
N'_γ	4.35

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	3.00	3.00	1.32	1.16	1.16
2	4.50	3.00	1.48	1.24	1.24
3	6.00	3.00	1.64	1.32	1.32

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	3.00	3.00	-0.50	0.50
2	4.50	3.00	-1.00	0.50
3	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2) General shea	Local shear	Actual
1	3.00	3.00	8.00	29.29	11.28	11.28
2	4.50	3.00	8.00	31.31	12.06	12.06
3	6.00	3.00	8.00	33.33	12.84	12.84

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

Location	Major Bridge
Chainage	179/31-37
Bore Hole No.	A2

Footing Depth (m)	1.50
SBC (t/m2)	15.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	27.00
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	19.7

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	28.80
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	19.1

Footing Depth (m)	4.50
SBC (t/m2)	18.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	32.40
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	18.9

Footing Depth (m)	6.00
SBC (t/m2)	19.00
Average N value	16.00
Settlement for 10 t/m2 (mm)	18.00
Total Settlement (mm)	34.20
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	18.6

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Major Bridge
Chainage	179/31-37
Bore Hole No.	A2

Footing Depth (m)	3.00
SBC (t/m2)	11.00
Average N value	18.00
Settlement for 10 t/m2 (mm)	17.00
Total Settlement (mm)	18.70
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	**12.4**

Footing Depth (m)	4.50
SBC (t/m2)	12.00
Average N value	19.00
Settlement for 10 t/m2 (mm)	16.00
Total Settlement (mm)	19.20
Depth Correction	0.73
Rigidity factor	0.8
Corrected Settlement (mm)	**11.2**

Footing Depth (m)	6.00
SBC (t/m2)	12.50
Average N value	19.00
Settlement for 10 t/m2 (mm)	16.00
Total Settlement (mm)	20.00
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	**10.9**

CHAPTER – 15

"Major Bridge No. 227",

Location – Existing Km. - 184/15-17

15.1 LOCATION OF STRUCTURE:

Proposed Major Bridge of Span ***1 x 24.40***

15.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***07.0m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1(A1)	0.00 to 4.50	Sandy Silt with Clay	Loose
	4.50 to 10.50	Sandy Silt with Clay & Gravels	Medium Dense
	10.50 to 12.00	Silty Sand with Gravels	Medium Dense
	12.00 to 19.50	Silty Sand	Medium Dense
	19.50 to 30.00	Silty Sand	Dense
BH-2(A2)	0.00 to 3.00	Silty Sand with Gravels	Loose
	3.00 to 4.50	Sandy Silt with Gravels	Loose
	4.50 to 7.50	Sandy Silt	Medium Dense
	7.50 to 9.00	Sandy Silt with Clay	Medium Dense
	9.00 to 22.50	Silty Sand	Dense
	22.50 to 25.50	Silty Sand	Dense
	25.50 to 28.50	Sandy Silt with Clay	Dense
	28.50 to 30.00	Silty Sand	Dense
	Below 30.00	Sandy Silt with Clay	Dense

15.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1 (A1)	3.00	7.60	NIL	0.0021	NIL	0.0012	0.039
	12.00	8.60	0.005	0.0017	NIL	0.0012	0.012
	21.00	8.70	NIL	0.0022	NIL	0.0012	0.0049
BH-2 (A2)	3.00	8.20	NIL	0.0017	NIL	0.0011	0.024
	9.00	8.50	0.002	0.0014	NIL	0.0011	0.007
	24.00	7.90	NIL	0.0021	NIL	0.0011	0.039

15.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1(A1)	3.00	20.00

	12.00	NIL
	21.00	NIL
BH-2 (A2)	3.00	NIL
	9.00	NIL
	24.00	NIL

15.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.9	138	99	149	756	0.3	2.8	912	1456
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

15.6 PILE LOAD CARRYING CAPACITY

15.6.1 Normal Bored Cast in- situ Pile Foundations:

Normal bored cast in situ RCC pile foundation is envisaged for the proposed bridge and have been analysed in the subsequent paragraphs. The Axial load carrying capacity of Pile in Rock is determined as per IRC- 78: 2000 appendix-5.

The safe Load carrying capacities of piles have been worked out on the basis of IRC-78 as per provision/assumptions provided therein.. For calculating designed Capacity of pile recommendation of IS: 2911 should be followed. The minimum factor of safety on ultimate axial capacity should be as per clause 709.3.2 of IRC 78: 2000.The final design/construction of foundations, the safe /allowable load carrying capacity of these piles should be taken by conducting actual initial load tests on these piles casted in the respective area.

Further the piles should have necessary structural strength to transmit/sustain the design load.

Safe bearing capacity in t/m²

BH - NO.	DEPTH (mtr)	Net Allowable Bearing Pressure (t/m²)
BH-1 (A1)	1.50	08.50
	3.00	11.00
	4.50	12.00
	6.00	13.00
BH-2 (A2)	1.50	12.00
	3.00	13.50

	4.50	15.00
	6.00	16.00

Pile load carrying capacity in t

BH -NO.	PILE DEPTH (mtr)	PILE CARRYING CAPACITY IN TONNE
		Pile Diameter= 1.20 m
BH-1 (A1)	17.00	220.00
	20.00	280.00
	23.00	350.00
BH-2 (A2)	17.00	225.00
	20.00	290.00
	23.00	360.00

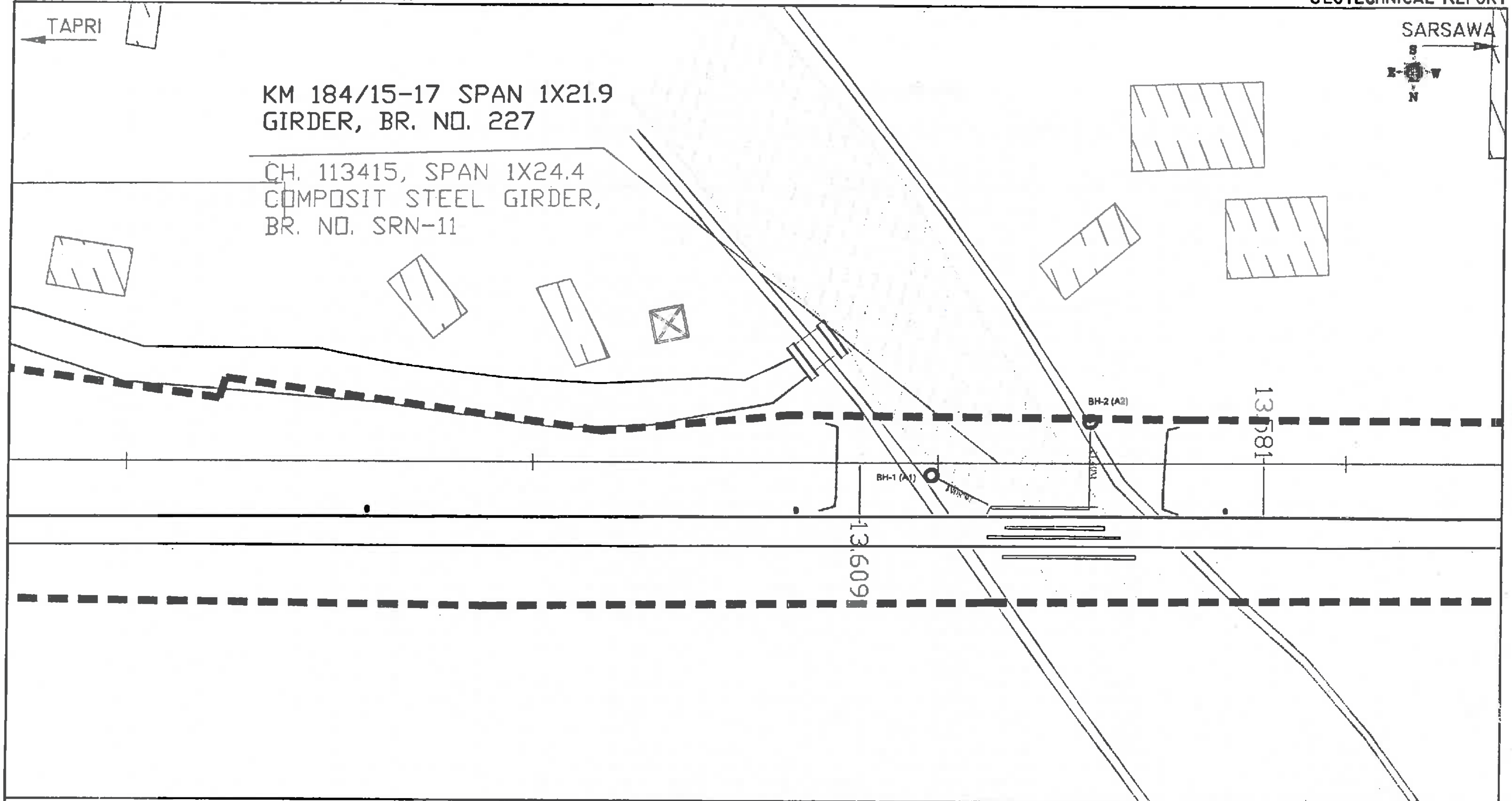
15.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

15.8 RECOMMENDATIONS

(i)	*Type of foundation*	Pile foundation

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MAJOR BRIDGE AT CH. 184/15-17	RL OF BH (AI) =277.943 RL OF BH (A2) =276.808	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE BH-A1 FOR MAJOR BRIDGE NO. 227 AT CHAINAGE 184/15-17

Project :	Chainage 184/15-17 Bridge No. 227	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		21.12.2009 to 22.12.2009	A1	1	07.00 m.	30.00mtr	

Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Sandy Silt with Clay	10.12	66.25	18.67	2.16	0.68	2.12	0.00	29	20	9	-	-	-	-	-	-
1.50	9	1.43	12.87	Sandy Silt with Clay	9.23	73.00	15.04	1.30	0.36	1.07	0.00	28	20	8	-	-	-	-	-	-
3.00	UDS	-	-	Sandy Silt with Clay	20.69	71.60	5.40	1.34	0.97	0.00	0.00	42	24	18	1.84	17.23	1.57	2.62	0.22	14.0
4.50	13	1.06	13.78	Sandy Silt with Clay & Gravels	9.82	76.42	6.76	0.82	0.32	5.86	0.00	29	21	8	-	-	-	-	-	-
7.50	17	0.89	15.07	Sandy Silt with Clay & Gravels	8.63	58.43	21.18	1.35	1.50	8.91	0.00	27	19	8	-	-	-	-	-	-
10.50	21	0.78	15.69	Silty Sand with Gravels	2.56	17.61	45.43	15.00	1.46	17.94	0.00	24	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Silty Sand	0.00	6.34	82.21	11.45	0.00	0.00	0.00	28	NIL	NP	1.98	20.00	1.65	2.72	0.00	29.0
13.50	27	0.69	16.82	Silty Sand	0.00	10.09	41.89	47.56	0.10	0.36	0.00	25	NIL	NP	-	-	-	-	-	-
16.50	28	0.62	16.18	Silty Sand	0.00	10.59	60.99	28.17	0.25	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
19.50	32	0.56	16.46	Silty Sand	0.00	5.60	63.52	30.26	0.62	0.00	0.00	24	NIL	NP	-	-	-	-	-	-
21.00	UDS	-	-	Silty Sand	0.00	7.78	60.23	31.21	0.26	0.52	0.00	25	NIL	NP	2.01	19.56	1.68	2.7	0	28.5
22.50	37	0.51	16.94	Silty Sand	0.00	8.45	58.71	32.52	0.07	0.25	0.00	24	NIL	NP	-	-	-	-	-	-
25.50	36	0.47	15.96	Silty Sand	0.00	8.47	55.49	35.37	0.36	0.31	0.00	23	NIL	NP	-	-	-	-	-	-
28.50	42	0.43	16.53	Silty Sand	2.16	8.90	51.02	37.64	0.28	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
30.00	53	0.41	18.37	Silty Sand	2.35	13.23	50.67	32.95	0.47	0.33	0.00	26	NIL	NP	-	-	-	-	-	-

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ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE BH-A2 FOR MAJOR BRIDGE NO. 227 AT CHAINAGE 184/15-17

Project :	Chainage 184/15-17 Bridge No. 227	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		20.12.2009 to 21.12.2009	A2	2	07.00 m.	30.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_c	Soil Description (Soil Group)	Clay	Silt	Sand Fine	Sand Medium	Sand Coarse	Gravel Fine	Gravel Coarse	L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength c kg/cm²	Shear Strength φ degree
0.00	-	-	-	Silty Sand with Gravels	2.68	9.80	60.45	20.42	0.31	6.34	0.00	25	NIL	NP	-	-	-	-	-	-
1.50	8	1.45	11.60	Silty Sand with Gravels	0.00	7.85	60.89	25.85	0.29	5.12	0.00	28	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand with Gravels	4.15	64.58	17.47	0.44	0.27	13.09	0.00	32	NIL	NP	1.75	13.01	1.55	2.68	0.00	31.0
4.50	12	1.08	12.96	Sandy Silt	3.65	48.35	47.00	1.00	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
7.50	14	0.91	12.74	Sandy Silt with Clay	14.32	69.66	14.46	0.40	0.10	1.06	0.00	39	27	12	-	-	-	-	-	-
9.00	UDS	-	-	Silty Sand	3.85	11.19	61.86	22.86	0.24	0.00	0.00	30	NIL	NP	1.89	21.13	1.56	2.61	0.00	29.0
10.50	21	0.79	15.80	Silty Sand	3.26	18.28	46.98	30.60	0.13	0.75	0.00	27	NIL	NP	-	-	-	-	-	-
13.50	23	0.70	15.55	Silty Sand	4.19	21.15	71.29	3.37	0.00	0.00	0.00	31	NIL	NP	-	-	-	-	-	-
16.50	26	0.63	15.69	Silty Sand	3.84	19.75	14.80	53.22	4.41	3.98	0.00	25	NIL	NP	-	-	-	-	-	-
19.50	27	0.58	15.33	Silty Sand	3.52	11.53	29.42	48.89	2.00	4.64	0.00	24	NIL	NP	-	-	-	-	-	-
22.50	30	0.53	15.45	Silty Sand	3.16	4.90	49.98	35.60	2.84	3.52	0.00	26	NIL	NP	-	-	-	-	-	-
24.00	UDS	-	-	Silty Sand	3.76	12.11	72.30	6.67	2.82	2.34	0.00	26	NIL	NP	2.10	19.86	1.75	2.67	0.00	29.0
25.50	35	0.48	15.90	Sandy Silt with Clay	9.54	71.44	11.05	2.69	0.99	4.29	0.00	30	22	8	-	-	-	-	-	-
28.50	46	0.44	17.62	Silty Sand	3.26	6.77	36.83	51.50	0.73	0.91	0.00	27	NIL	NP	-	-	-	-	-	-
30.00	51	0.40	17.70	Sandy Silt with Clay	12.14	49.48	31.27	2.60	1.61	2.90	0.00	38	28	10	-	-	-	-	-	-

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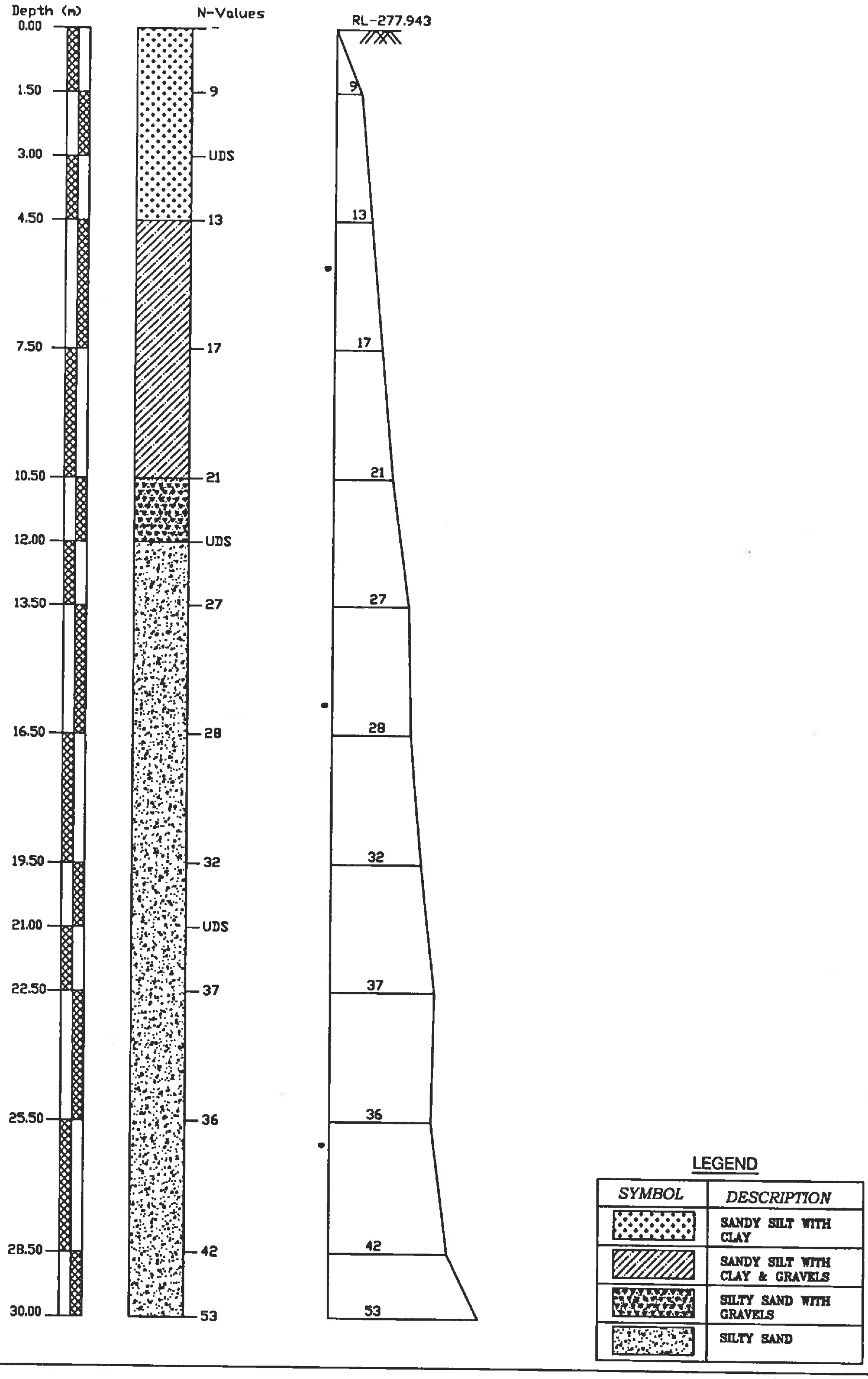
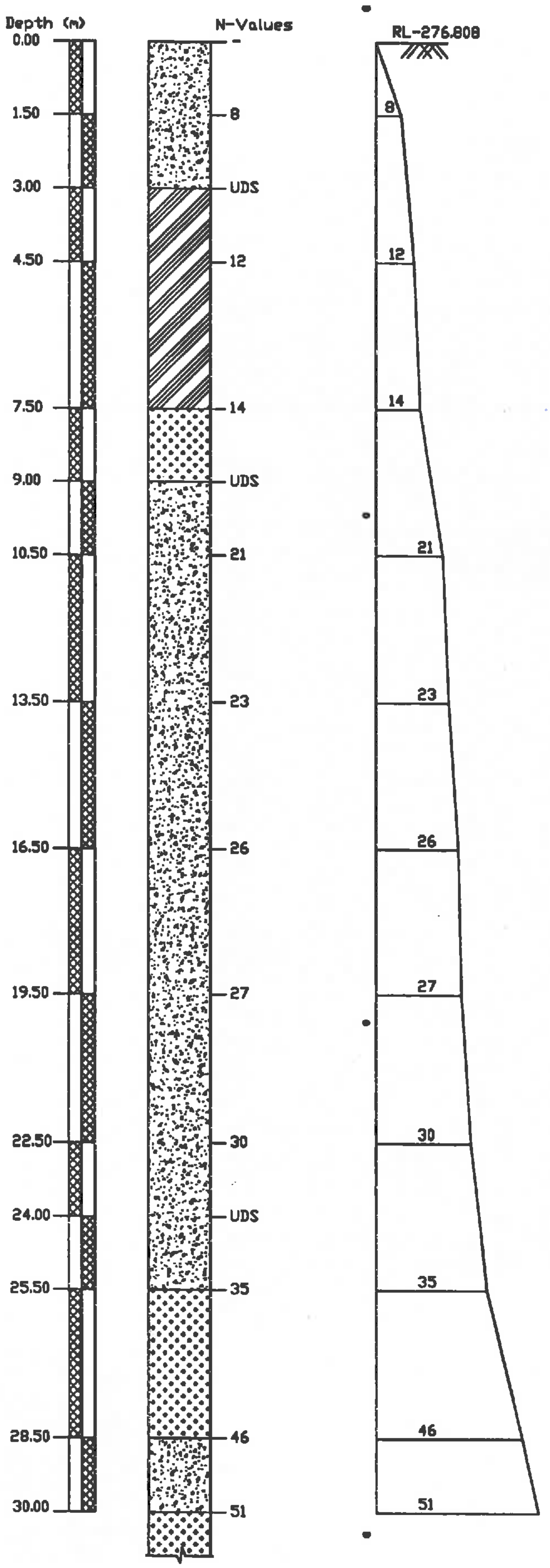
BORELOG OF BH-1(A1) AT EXISTING KM-184/15-17 FOR MAJOR BRIDGE NO.-227, ON KESARI TO SANEHWAL, LUDHIANA



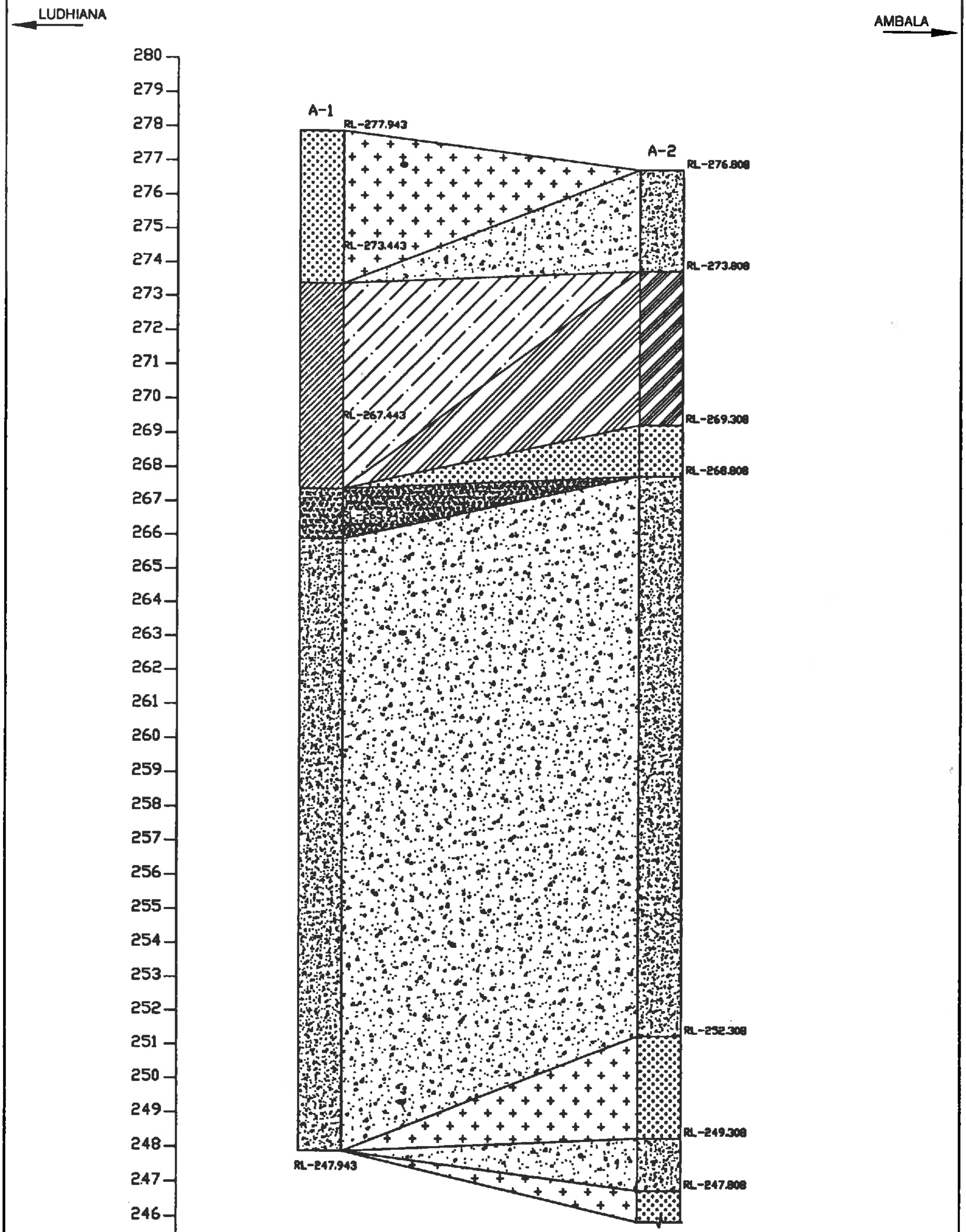
BORELOG OF BH–2(A2) AT EXISTING KM–184/15–17 FOR MAJOR BRIDGE NO.–227,
ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND
	SANDY SILT
	SANDY SILT WITH CLAY

BORE HOLE DETAIL AT MAJOR BRIDGE NO. 227, CH.- 184/15-17



LEGEND

SYMBOL	DESCRIPTION
	SANDY SILT WITH CLAY
	SANDY SILT WITH CLAY & GRAVELS
	SILTY SAND WITH GRAVELS
	SILTY SAND
	SANDY SILT

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 184 15-17 **BH-A1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	14.00
Cohesion (c in t/m2)	2.20
Void ratio (e)	0.68
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.84
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	14.00
N_c	10.45
N_q	3.65
N_γ	2.36

ϕ'	9.48
N'_c	8.16
N'_q	2.38
N'_γ	1.14

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.13	1.06	1.06
2	3.00	3.00	1.26	1.13	1.13
3	4.50	3.00	1.38	1.19	1.19
4	6.00	3.00	1.51	1.26	1.26

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	15.42	7.99	10.59
2	3.00	3.00	8.00	16.85	8.73	11.57
3	4.50	3.00	8.00	18.27	9.47	12.55
4	6.00	3.00	8.00	19.69	10.20	13.53

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 184 15-17 **BH-A2**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.73
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.75
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)^*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)^*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.17	1.08	1.08
2	3.00	3.00	1.33	1.17	1.17
3	4.50	3.00	1.50	1.25	1.25
4	6.00	3.00	1.67	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	3.00	8.00	35.48	12.39	14.70
2	3.00	3.00	8.00	38.21	13.34	15.83
3	4.50	3.00	8.00	40.93	14.30	16.96
4	6.00	3.00	8.00	43.66	15.25	18.09

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)

Depth of foundation		=	1.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	6.75	t/m^2
Concentrated load *P*		=	8.50	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	1.9	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_0	=	0.68	

$$\frac{Po + \Delta p}{Po} = 1.27704$$

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

$$S_f = 0.03414 \text{ m}$$

$$= 34.1368 \text{ mm}$$

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.31

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.91

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

= N.A.

Total Settlement = $S_f \times$ D.F.x R.F.

S_{f2} = 24.9 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)

Depth of foundation		=	3.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	9.45	t/m^2
Concentrated load *P*		=	11.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	2.4	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.68	

$$\frac{Po + \Delta p}{Po} = 1.25608$$

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

$$S_f = 0.03183 \text{ m}$$

$$= 31.8275 \text{ mm}$$

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5} = 0.61$

D = Depth of Foundation

L/B = 2.67

Depth Factor = 0.83

Rigidity Factor = $\dfrac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$

= 0.8

= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 21.1 mm

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)

Depth of foundation		=	4.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	12.15	t/m^2
Concentrated load P		=	12.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	2.6	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.68	

$$\frac{Po + \Delta p}{Po} = 1.21728$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} H \log_{10} \frac{Po + \Delta P}{Po}$$

$$S_f = 0.02745 \text{ m}$$

$$= 27.4474 \text{ mm}$$

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$$D/(LB)^{0.5} = 0.92$$

D = Depth of Foundation

$$L/B = 2.67$$

Depth Factor = 0.73

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

= N.A.

Total Settlement = S_f x D.F.x R.F.

$$S_{f2} = 16.0 \text{ mm}$$

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

BH No. (A1)

Depth of foundation		=	6.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	3.0	m
Initial effective stress at mid of layer	Po	=	14.85	t/m^2
Concentrated load *P*		=	13.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.22	
	ΔP	=	2.9	t/m^2
Compression Index	Cc	=	0.12	
Thickness of clay layer	H	=	4.5	m
Initial Void ratio	e_o	=	0.68	

$$\frac{Po + \Delta p}{Po} = 1.19259$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

$$S_f = 0.02459 \text{ m}$$

$$= 24.5867 \text{ mm}$$

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$$(LB)^{0.5}/D = 0.82$$

D = Depth of Foundation

$$L/B = 2.67$$

Depth Factor = 0.68

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 13.4 mm

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Major Bridge
Chainage	184/15-17
Bore Hole No.	A2

Footing Depth (m)	1.50
SBC (t/m2)	12.00
Average N value	12.00
Settlement for 10 t/m2 (mm)	27.00
Total Settlement (mm)	32.40
Depth Correction	0.91
Rigidity factor	0.8
Corrected Settlement (mm)	23.6

Footing Depth (m)	3.00
SBC (t/m2)	13.50
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	32.40
Depth Correction	0.83
Rigidity factor	0.8
Corrected Settlement (mm)	21.5

Footing Depth (m)	4.50
SBC (t/m2)	15.00
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	36.00
Depth Correction	0.74
Rigidity factor	0.8
Corrected Settlement (mm)	21.3

Footing Depth (m)	6.00
SBC (t/m2)	16.00
Average N value	13.00
Settlement for 10 t/m2 (mm)	24.00
Total Settlement (mm)	38.40
Depth Correction	0.68
Rigidity factor	0.8
Corrected Settlement (mm)	20.9

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CHAPTER – 14

"Minor Bridge No. 211",

Location – Existing Km. – 172/900-173/000

14.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span ***1x 6x4***

14.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***6.50m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

14.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.60	0.005	0.0014	NIL	0.0011	0.016
	9.00	7.90	NIL	0.0014	NIL	0.0011	0.017

14.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	9.00	NIL

14.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.1	72	139	128	689	0.4	3.8	830	1362
Requirement as per IS 456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

14.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	09.50
	3.00	13.00
	4.50	17.00
	6.00	19.00

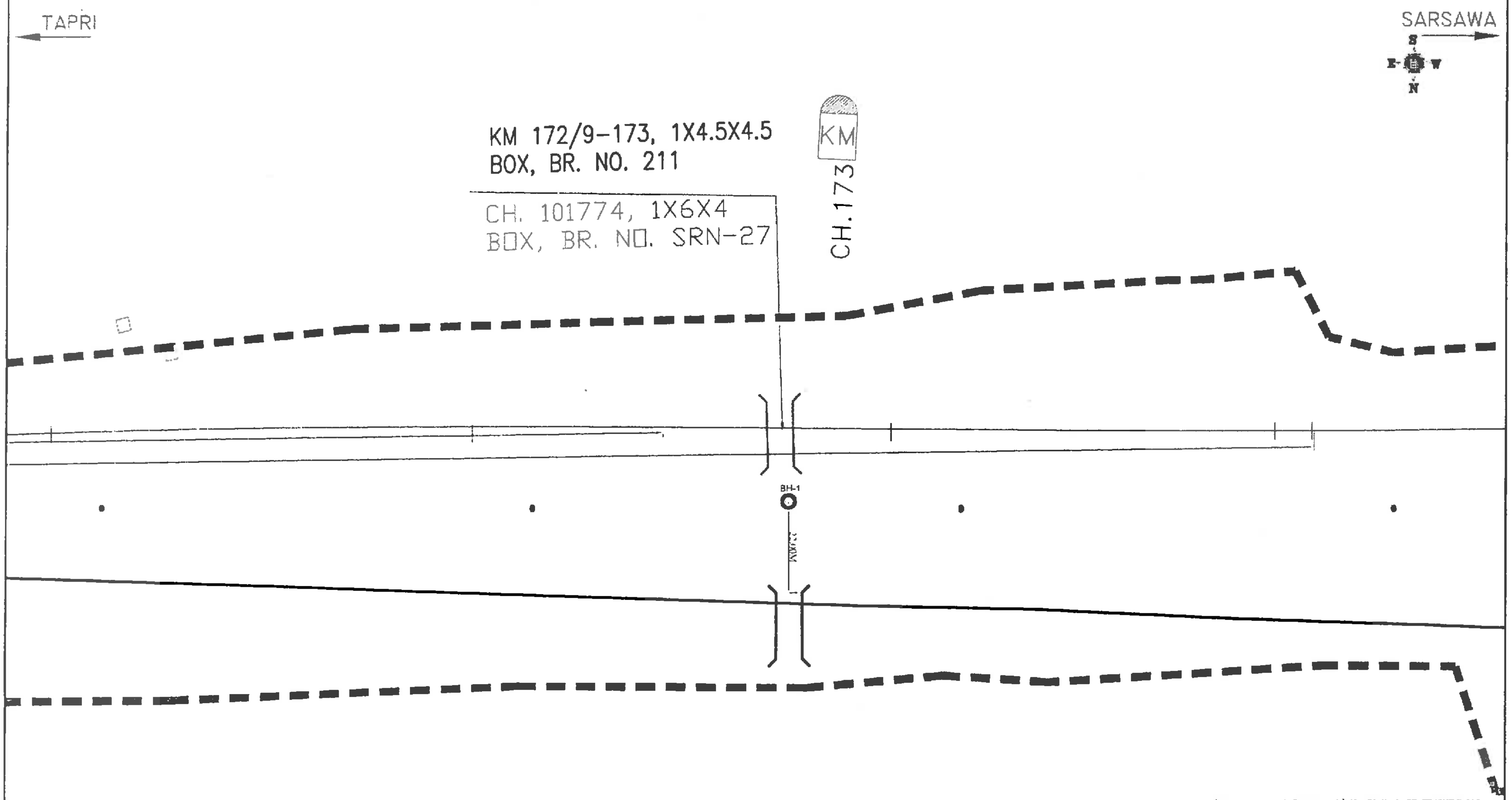
14.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

14.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 172/900-173/000	RL OF BH I = 270.193	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 211 AT CHAINAGE 172/900 - 173/000

Project :	Chainage 172/900-173/000 Bridge No. 211	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		30.12.2009 to 30.12.2009	1	1	07.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Clay	Silt	Sand Fine	Sand Medium	Sand Coarse	Gravel Fine	Gravel Coarse	Atterberg Limits % L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength c kg/cm²	ϕ degree
0.00	-	-	-	Silty Sand	3.68	33.32	50.36	12.64	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
1.50	7	1.43	10.01	Silty Sand	4.38	34.88	49.83	10.91	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	3.55	8.49	86.57	1.39	0.00	0.00	0.00	25	NIL	NP	1.78	14.77	1.55	2.68	0.00	27.0
4.50	12	1.06	12.72	Silty Sand	3.68	39.42	51.64	5.26	0.00	0.00	0.00	24	NIL	NP	-	-	-	-	-	-
7.50	17	0.89	15.07	Silty Sand	3.26	9.28	48.48	38.98	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
9.00	UDS	-	-	Silty Sand	0.00	9.42	86.90	3.68	0.00	0.00	0.00	29	NIL	NP	1.89	18.53	1.59	2.66	0.00	28.0
10.50	20	0.77	15.20	Silty Sand	3.68	23.37	40.68	32.15	0.12	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
12.00	26	0.73	16.99	Silty Sand	3.89	21.07	41.25	31.44	0.09	2.26	0.00	26	NIL	NP	-	-	-	-	-	-

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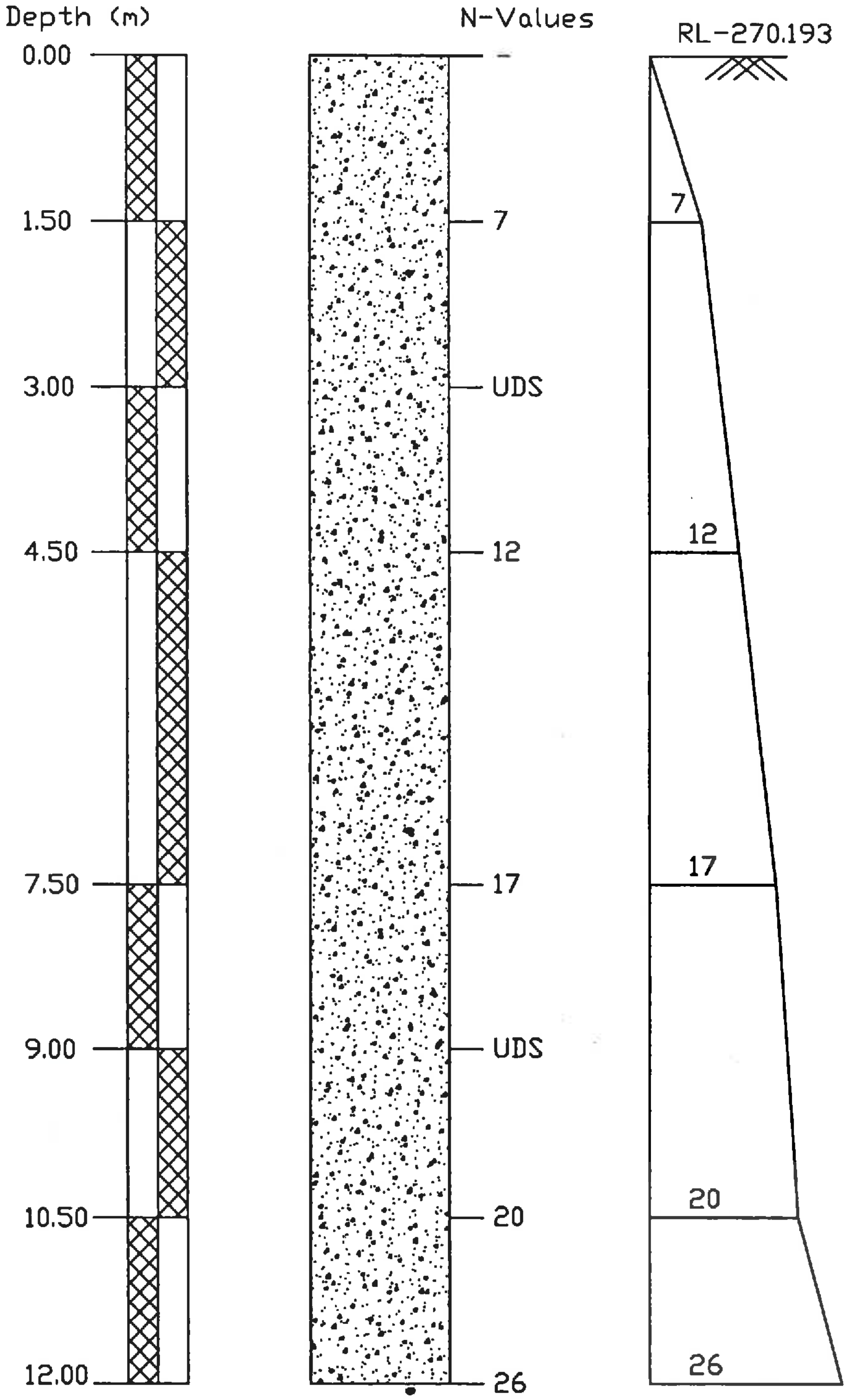
ANNEXURE-II

BORELOG OF BH-1 AT EXISTING KM-172/900-173/000 FOR MINOR BRIDGE NO.-211,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 172 900-173 000 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.73
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.78
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	6.00	8.00
2	3.00	6.00	8.00
3	4.50	6.00	8.00
4	6.00	6.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q\text{-}1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q\text{-}1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	6.00	8.00	1.15	1.15	0.70
2	6.00	8.00	1.15	1.15	0.70
3	6.00	8.00	1.15	1.15	0.70
4	6.00	8.00	1.15	1.15	0.70

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	6.00	1.08	1.04	1.04
2	3.00	6.00	1.16	1.08	1.08
3	4.50	6.00	1.24	1.12	1.12
4	6.00	6.00	1.33	1.16	1.16

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	6.00	0.00	0.50
2	3.00	6.00	-0.25	0.50
3	4.50	6.00	-0.50	0.50
4	6.00	6.00	-0.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	6.00	8.00	23.02	8.00	9.51
2	3.00	6.00	8.00	37.41	13.43	15.83
3	4.50	6.00	8.00	52.82	19.24	22.60
4	6.00	6.00	8.00	69.24	25.43	29.81

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	172/900-173/000
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	9.50
Average N value	13
Settlement for 10 t/m2 (mm)	30.00
Total Settlement (mm)	28.50
Depth Correction	0.9
Rigidity Factor	0.8
Corrected Settlement (mm)	20.5

Footing Depth (m)	3.00
SBC (t/m2)	13.00
Average N value	14
Settlement for 10 t/m2 (mm)	27.00
Total Settlement (mm)	35.10
Depth Correction	0.87
Rigidity Factor	0.8
Corrected Settlement (mm)	24.4

Footing Depth (m)	4.50
SBC (t/m2)	17.00
Average N value	15
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	37.40
Depth Correction	0.81
Rigidity Factor	0.8
Corrected Settlement (mm)	24.2

Footing Depth (m)	6.00
SBC (t/m2)	19.00
Average N value	16
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	39.90
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	23.6

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'MAJOR BRIDGES'

CHAPTER - 13

"Minor Bridge No. 214",

Location - Existing Km. - 175/500 - 600

13.1 **LOCATION OF STRUCTURE:**
Proposed Minor Bridge of Span *1x 1.20 x 1.20*

13.2 **BOREHOLE DESCRIPTIONS:**

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *6.50m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 7.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

13.3 **CHEMICAL ANALYSIS OF SOIL:**

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.20	NIL	0.0026	NIL	0.0011	0.044
	6.00	8.30	0.007	0.0028	NIL	0.0011	0.034

13.4 **DIFFERENTIAL FREE SWELL INDEX (DFS)**

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

13.5 **CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE**

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.0	74	139	135	685	0.4	4.6	832	1309
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

13.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	6.00
	3.00	6.50
	4.50	9.50
	6.00	11.50

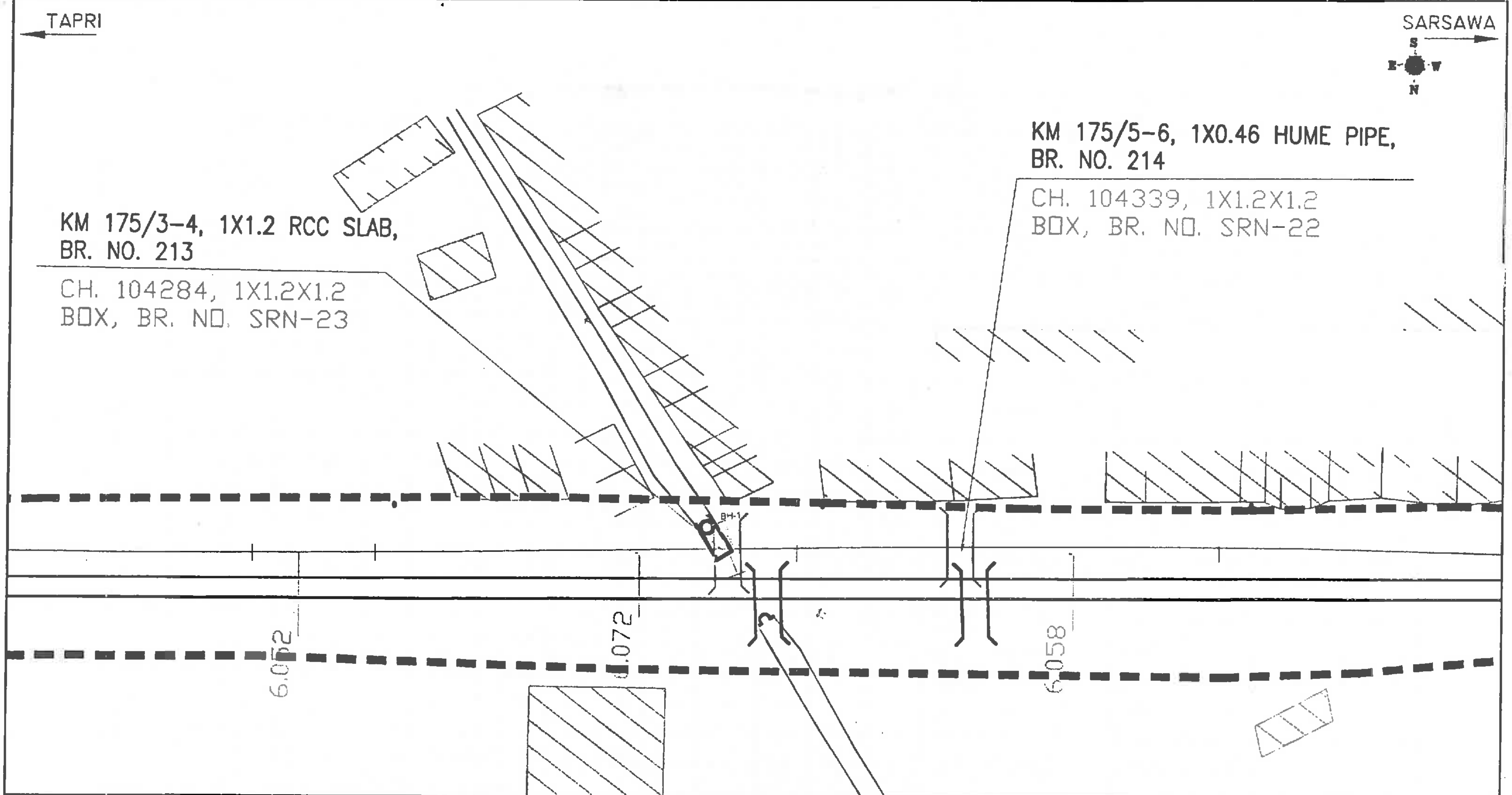
13.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

13.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open & Raft foundation
(ii)	*Depth of foundation below GL*	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 175/500-600	RL OF BH-I =272.913	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CEG CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 214 AT CHAINAGE 175/500

Project :	Chainage 175/500 Bridge No. 214	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		29.12.2009 to 29.12.2009	1	1	06.50 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm^2	ϕ degree
0.00	-	-	-	Silty Sand	2.68	12.80	80.26	4.26	0.00	0.00	0.00	24	NIL	NP	-	-	-	-	-	-
1.80	DS	-	-	Silty Sand	2.98	15.72	77.62	3.68	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	2.99	15.59	78.44	2.98	0.00	0.00	0.00	26	NIL	NP	1.68	8.36	1.55	2.64	0.00	28.0
4.50	5	1.09	5.45	Silty Sand	2.68	11.43	70.49	15.40	0.00	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	4.25	10.90	83.53	1.32	0.00	0.00	0.00	29	NIL	NP	1.75	13.39	1.50	2.65	0.00	27.5
7.50	11	0.91	10.01	Silty Sand	4.25	8.46	71.54	15.75	0.00	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
10.50	12	0.79	9.48	Silty Sand	4.36	30.13	58.90	6.61	0.00	0.00	0.00	31	NIL	NP	-	-	-	-	-	-
12.00	15	0.75	11.25	Silty Sand	4.00	8.83	85.56	1.61	0.00	0.00	0.00	30	NIL	NP	-	-	-	-	-	-

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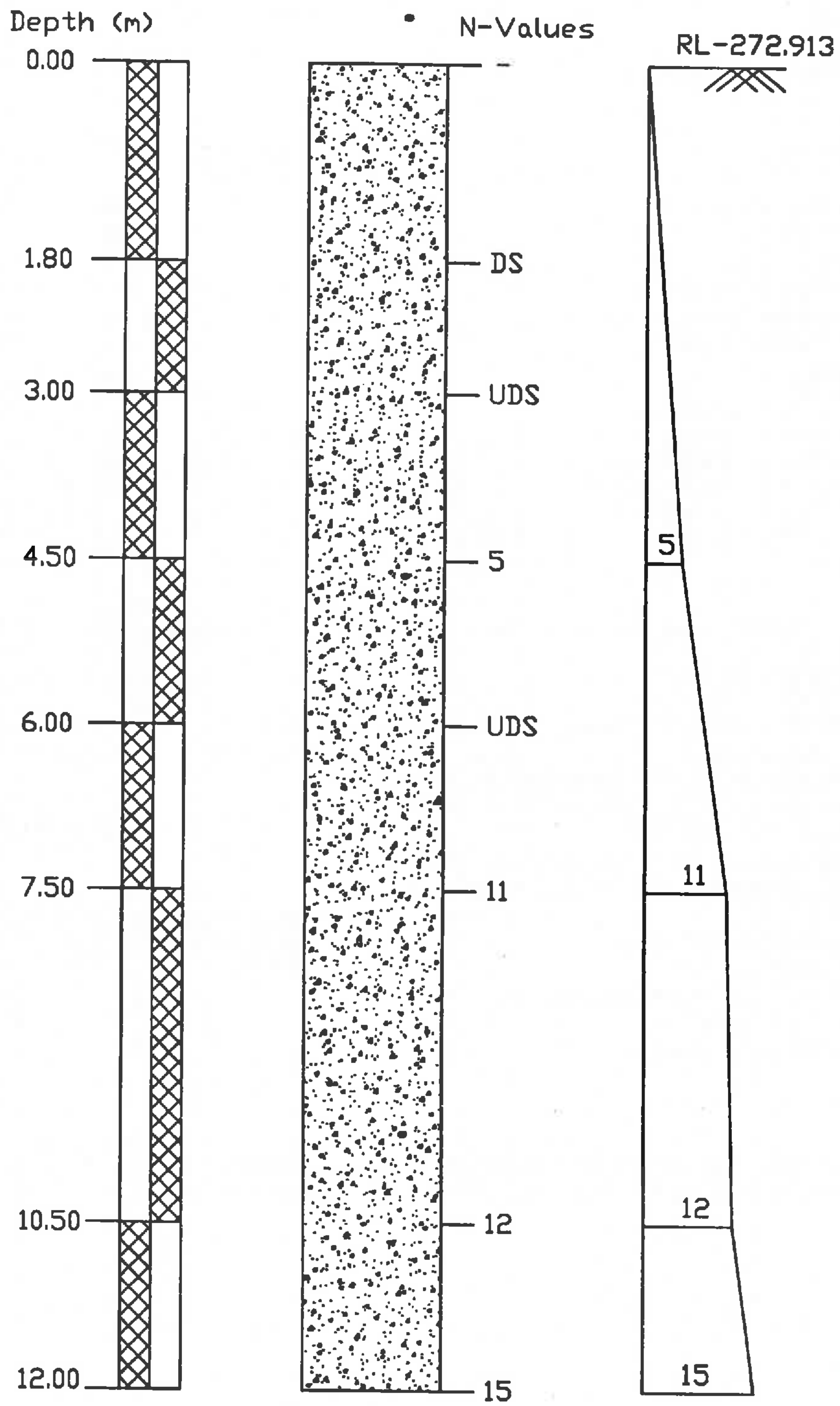
BORELOG OF BH–1 AT EXISTING KM–175/500–600 FOR MINOR BRIDGE NO.–214, ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 175 500-600 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Continuous Strip | 1

Angle of internal friction (ϕ °)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.68
Density of foundation soil (t/m³)	1.68
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)
1	1.50	1.20
2	3.00	1.20
3	4.50	1.20
4	6.00	1.20

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$q_d = c\, N_c s_c d_c i_c + q\,(N_q-1)\, s_q d_q i_q + (1/2)\, B\, \gamma\, N_\gamma s_\gamma d_\gamma i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by

$q'_d = (2/3)\, c\, N'_c s_c d_c i_c + q\,(N'_q-1)\, s_q d_q i_q + (1/2)\, B\, \gamma\, N'_\gamma s_\gamma d_\gamma i_\gamma W'$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	S_c	S_q	S_γ
1	1.20	1.00	1.00	1.00
2	1.20	1.00	1.00	1.00
3	1.20	1.00	1.00	1.00
4	1.20	1.00	1.00	1.00

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.42	1.21	1.21
2	3.00	1.20	1.83	1.42	1.42
3	4.50	1.20	2.25	1.62	1.62
4	6.00	1.20	2.66	1.83	1.83

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	SBC in (t/m^2)		
			General shear	Local shear	Actual
1	1.50	1.20	15.22	5.28	7.76
2	3.00	1.20	17.84	6.19	9.10
3	4.50	1.20	20.47	7.10	10.44
4	6.00	1.20	23.09	8.00	11.77

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	175/500-600
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	6.00
Average N value	5
Settlement for 10 t/m2 (mm)	100.00
Total Settlement (mm)	60.00
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	**39.8**

Footing Depth (m)	3.00
SBC (t/m2)	6.50
Average N value	5
Settlement for 10 t/m2 (mm)	100.00
Total Settlement (mm)	65.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	**38.0**

Footing Depth (m)	4.50
SBC (t/m2)	9.50
Average N value	6
Settlement for 10 t/m2 (mm)	80.00
Total Settlement (mm)	76.00
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	**38.3**

Footing Depth (m)	6.00
SBC (t/m2)	17.00
Average N value	9
Settlement for 10 t/m2 (mm)	44.00
Total Settlement (mm)	74.80
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	**37.7**

CHAPTER - 12

"Minor Bridge No. 215",

Location - Existing Km. - 176/200 - 300

12.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span *1x 1.20 x 1.20*

12.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *7.00m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 7.50	Silty Sand	Loose
	7.50 to 12.00	Silty Sand	Medium Dense
	Below 12.00	Clayey Silt	Medium Dense

12.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	7.90	NIL	0.0017	NIL	0.0012	0.029
	12.00	8.70	0.005	0.0021	NIL	0.0011	0.034

12.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	12.00	15.00

12.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.2	71	126	129	683	0.5	4.8	825	1275
Requirement as per IS 456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

12.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	08.50
	3.00	10.00
	4.50	11.50
	6.00	13.00

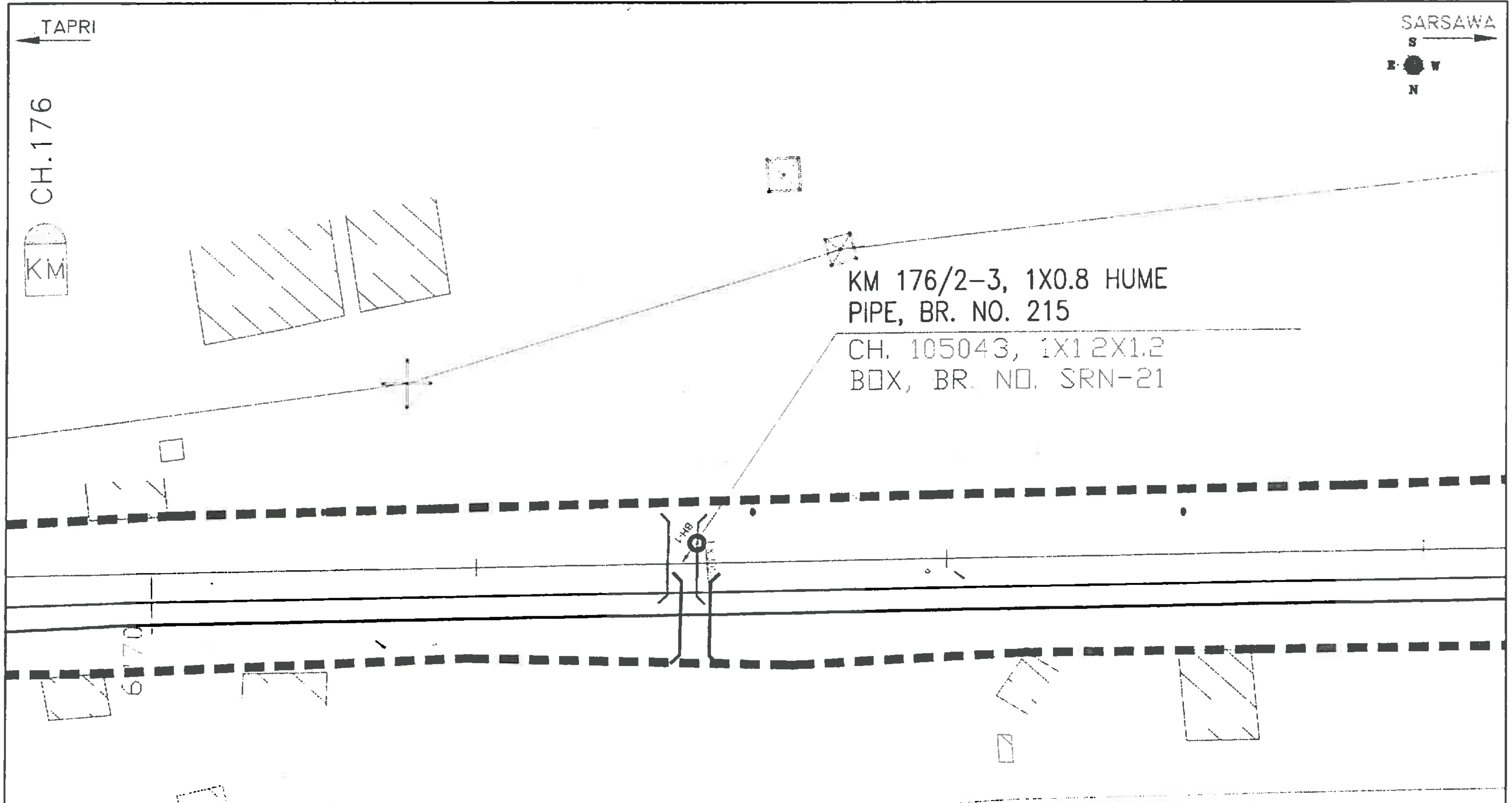
12.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

12.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 176/200-300	RL OF BH-I =272.903	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 215 AT CHAINAGE 176/200

Project :	Chainage 176/200 Bridge No. 215	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		28.12.2009 to 28.12.2009	1	1	07.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm²	ϕ degree
0.00	-	-	-	Silty Sand	3.56	11.07	82.39	20.36	2.62	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
1.30	DS	-	-	Silty Sand	3.68	11.40	65.25	18.52	1.15	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
1.50	8	1.44	11.52	Silty Sand	4.15	19.19	60.50	16.08	0.08	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	4.26	13.55	80.97	1.22	0.00	0.00	0.00	30	NIL	NP	1.80	13.85	1.58	2.66	0.00	27.5
4.50	8	1.07	8.56	Silty Sand	0.00	6.99	58.87	34.09	0.05	0.00	0.00	29	NIL	NP	-	-	-	-	-	-
7.50	12	0.90	10.80	Silty Sand	0.00	5.47	63.17	31.36	0.00	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
10.50	15	0.79	11.85	Silty Sand	0.00	6.51	54.49	38.85	0.15	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Clayey Silt	15.96	81.30	2.01	0.51	0.22	0.00	0.00	42	29	13	1.86	23.10	1.51	2.58	0.14	17.0

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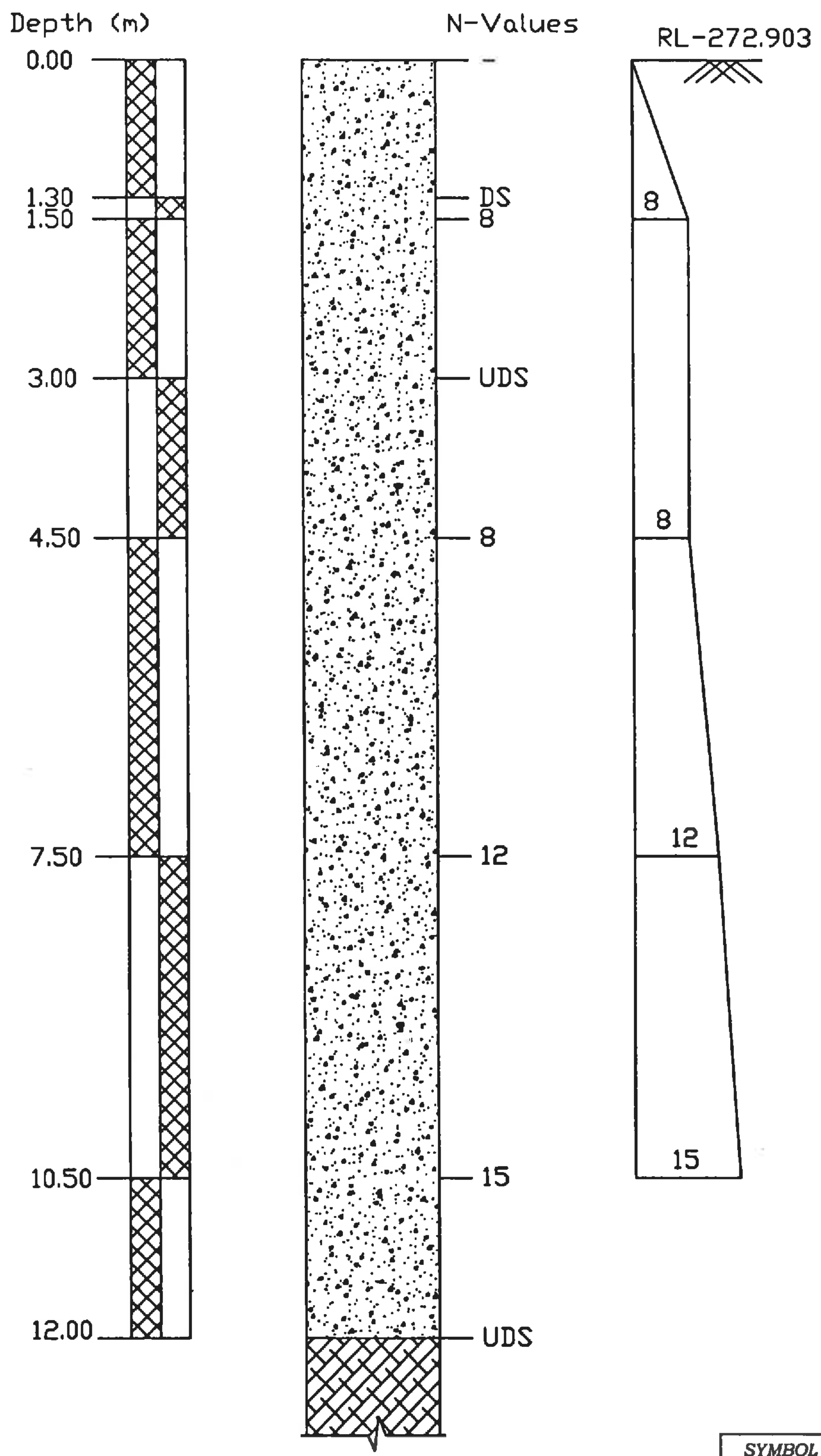
BORELOG OF BH-1 AT EXISTING KM-176/200-300 FOR MINOR BRIDGE NO.-215,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND
	CLAYEY SILT

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

	Ch 176 200-300	BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular | 2

Angle of internal friction (ϕ °)	27.50
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.68
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.80
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	1.20	8.00
2	3.00	1.20	8.00
3	4.50	1.20	8.00
4	6.00	1.20	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q\text{-}1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q\text{-}1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.50
N_c	25.43
N_q	14.53
N_γ	16.64

ϕ'	19.23
N'_c	14.24
N'_q	6.02
N'_γ	4.97

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	1.20	8.00	1.03	1.03	0.94
2	1.20	8.00	1.03	1.03	0.94
3	1.20	8.00	1.03	1.03	0.94
4	1.20	8.00	1.03	1.03	0.94

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.41	1.21	1.21
2	3.00	1.20	1.82	1.41	1.41
3	4.50	1.20	2.24	1.62	1.62
4	6.00	1.20	2.65	1.82	1.82

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	1.20	8.00	14.82	5.25	8.60
2	3.00	1.20	8.00	17.36	6.15	10.07
3	4.50	1.20	8.00	19.89	7.05	11.54
4	6.00	1.20	8.00	22.42	7.95	13.01

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

Location	Minor Bridge
Chainage	176/200-300
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	8.50
Average N value	10
Settlement for 10 t/m2 (mm)	36.00
Total Settlement (mm)	30.60
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	20.3

Footing Depth (m)	3.00
SBC (t/m2)	10.00
Average N value	10
Settlement for 10 t/m2 (mm)	36.00
Total Settlement (mm)	36.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	21.0

Footing Depth (m)	4.50
SBC (t/m2)	11.50
Average N value	9
Settlement for 10 t/m2 (mm)	44.00
Total Settlement (mm)	50.60
Depth Correction	0.62
Rigidity Factor	0.8
Corrected Settlement (mm)	25

Footing Depth (m)	6.00
SBC (t/m2)	13.00
Average N value	10
Settlement for 10 t/m2 (mm)	28.00
Total Settlement (mm)	36.40
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	18.3

CHAPTER - 11

"Minor Bridge No. 216",

Location - Existing Km. - 178/02-03

11.1 LOCATION OF STRUCTURE:
Proposed Minor Bridge of Span 1x2x2

11.2 BOREHOLE DESCRIPTIONS:
(a) Location of Structure, Boreholes with RL shown in FIGURE-1.
(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*
(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*
(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*
(e) Calculations of Probable Settlement in *ANNEXURE-IV.*
(f) Depth of water Table *7.00m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 3.00	Silty Sand with Gravels	Loose
	3.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

11.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	7.90	NIL	0.0028	NIL	0.0012	0.088
	6.00	7.90	NIL	0.0017	NIL	0.0011	0.029

11.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

11.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.7	60	128	110	712	0.3	4.6	830	1293
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

11.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	07.00
	3.00	11.00
	4.50	13.50
	6.00	15.00

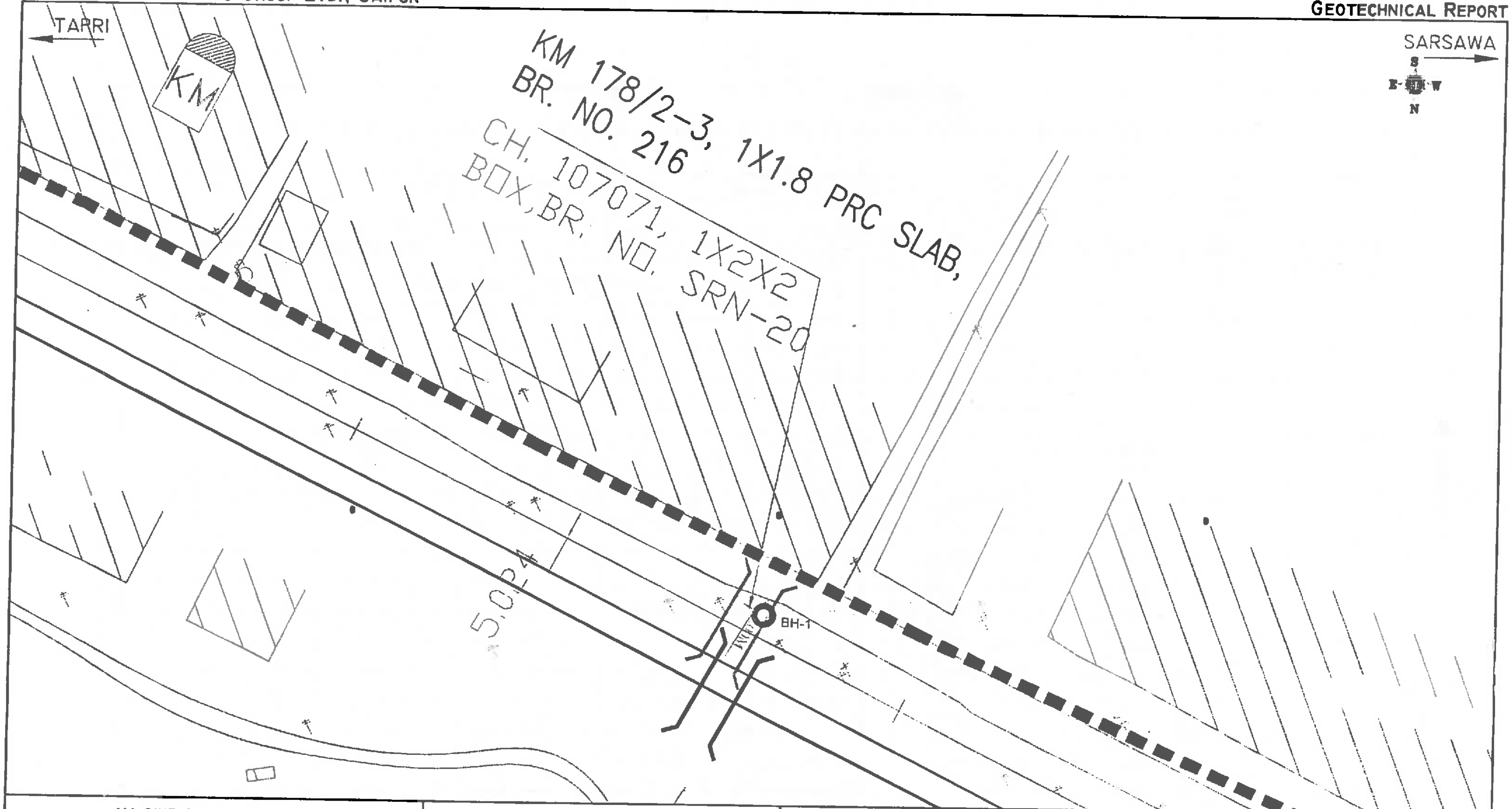
11.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

11.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER	RL OF BH-I =274.103	PROJECT :-	DESIGN :-
FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 178/02/03		LUDHIANA-AMBALA (DFCCIL)	CEG CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 217 AT CHAINAGE 178/02-03

Project :	Chainage 178/02-03 Bridge No. 217			Date of Testing	Location at		B.H. No.			Depth of Water Table		Termination Depth			Surface Elevation						
				27.12.2009 to 27.12.2009	1		1			07.00 m.		12.00mtr									
Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm^2	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Silty Sand with Gravels	3.65	25.71	42.39	20.15	1.52	6.58	0.00	25	NIL	NP	-	-	-	-	-	-
1.50	5	1.40	7.00	Silty Sand with Gravels	3.86	26.55	41.72	16.20	1.77	9.90	0.00	27	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	2.85	35.10	53.50	8.55	0.00	0.00	0.00	22	NIL	NP	1.70	8.50	1.56	2.67	0.00	27.0
4.50	10	1.04	10.40	Silty Sand	3.68	13.74	61.57	21.01	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	0.00	6.84	78.80	13.95	0.41	0.00	0.00	29	NIL	NP	1.98	18.15	1.78	2.68	0.00	28.0
7.50	15	0.86	12.90	Silty Sand	0.00	6.64	78.53	14.83	0.00	0.00	0.00	29	NIL	NP	-	-	-	-	-	-
10.50	18	0.74	13.32	Silty Sand	3.69	17.29	75.46	3.42	0.14	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
12.00	24	0.70	15.90	Silty Sand	2.86	11.43	78.01	7.50	0.10	0.10	0.00	23	NIL	NP	-	-	-	-	-	-

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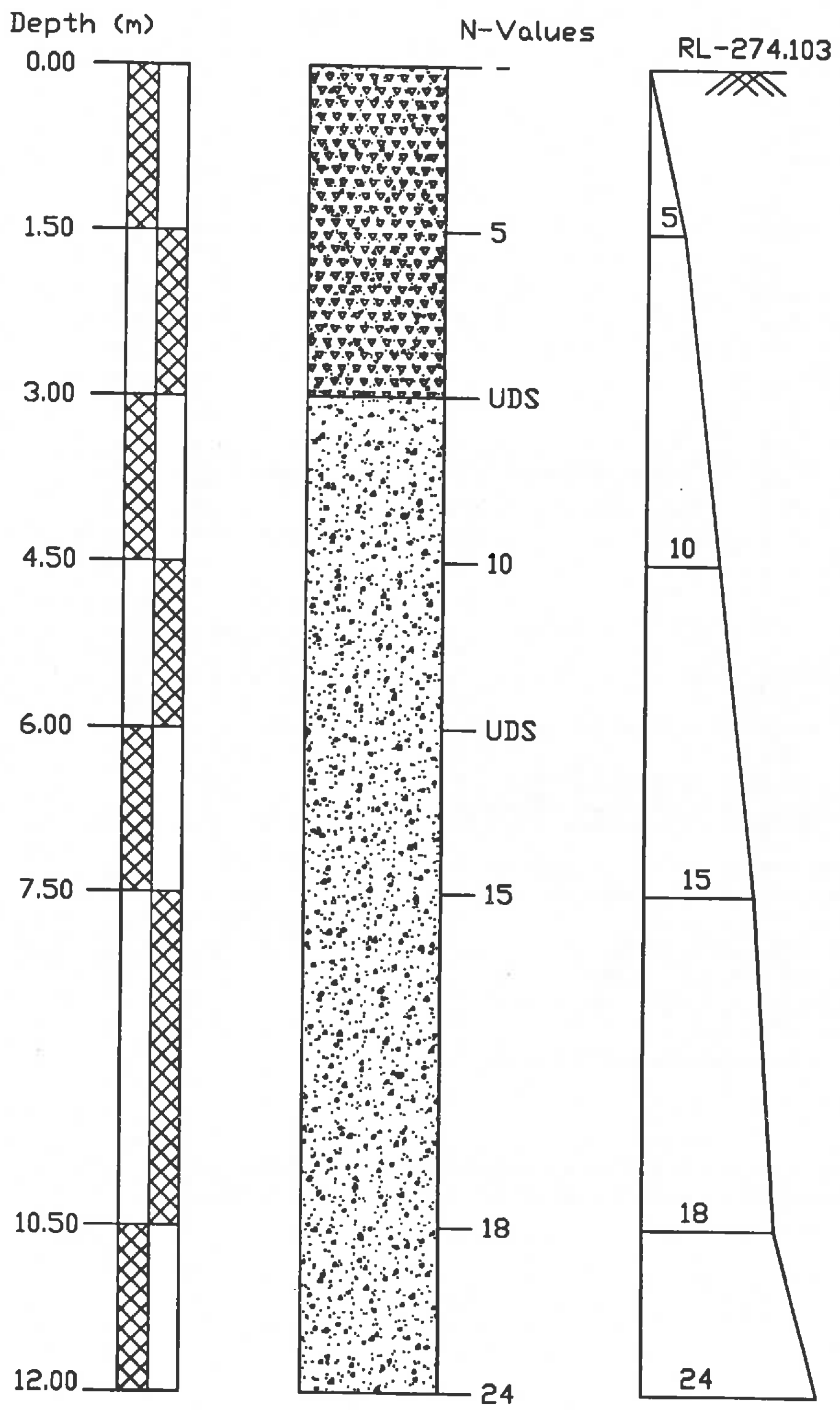
ANNEXURE-II

BORELOG OF BH–1 AT EXISTING KM–178/02–03 FOR MINOR BRIDGE NO.–216,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND WITH GRAVELS
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 178 2-3 **BH-1**

Type of footing

1 Continuous Strip

2 Rectangular

3 Square

4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m³)	1.80
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00
2	3.00	2.00	8.00
3	4.50	2.00	8.00
4	6.00	2.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c s_c d_c i_c + q\,(N_q - 1)\, s_q d_q i_q + (1/2)\, B\,\gamma N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c s_c d_c i_c + q\,(N'_q - 1)\, s_q d_q i_q + (1/2)\, B\,\gamma N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1 + 0.2\ (D_f/B)^*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\ (D_f/B)^*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90
3	2.00	8.00	1.05	1.05	0.90
4	2.00	8.00	1.05	1.05	0.90

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	2.00	1.24	1.12	1.12
2	3.00	2.00	1.49	1.24	1.24
3	4.50	2.00	1.73	1.37	1.37
4	6.00	2.00	1.98	1.49	1.49

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	2.00	0.00	0.50
2	3.00	2.00	-0.75	0.50
3	4.50	2.00	-1.50	0.50
4	6.00	2.00	-2.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shea	Local shear	Actual
1	1.50	2.00	8.00	21.73	7.90	11.36
2	3.00	2.00	8.00	24.10	8.76	12.59
3	4.50	2.00	8.00	26.47	9.62	13.83
4	6.00	2.00	8.00	28.84	10.48	15.07

CONSULTING Engineers Group Ltd.

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	178/02-03
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	7.00
Average N value	9
Settlement for 10 t/m2 (mm)	48.00
Total Settlement (mm)	33.60
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	**24.5**

Footing Depth (m)	3.00
SBC (t/m2)	11.00
Average N value	10
Settlement for 10 t/m2 (mm)	32.00
Total Settlement (mm)	35.20
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	**23.4**

Footing Depth (m)	**4.50**
SBC (t/m2)	13.50
Average N value	12
Settlement for 10 t/m2 (mm)	23.00
Total Settlement (mm)	31.05
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	**18.4**

Footing Depth (m)	**6.00**
SBC (t/m2)	15.00
Average N value	13
Settlement for 10 t/m2 (mm)	21.00
Total Settlement (mm)	31.50
Depth Correction	0.67
Rigidity Factor	0.8
Corrected Settlement (mm)	**16.9**

CHAPTER – 10

"Minor Bridge No. 217",

Location – Existing Km. – 178/30-32

CONSULTING Engineers Group Ltd.

10.1 LOCATION OF STRUCTURE:
Proposed Minor Bridge of Span *1x 6.10*

10.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *7.50m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

10.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.60	NIL	0.0021	NIL	0.0015	0.061
	6.00	8.90	NIL	0.0025	NIL	0.0015	0.067

10.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

10.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.1	74	132	125	682	0.4	3.9	821	1312
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

10.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	12.00
	3.00	13.00
	4.50	14.00
	6.00	15.00

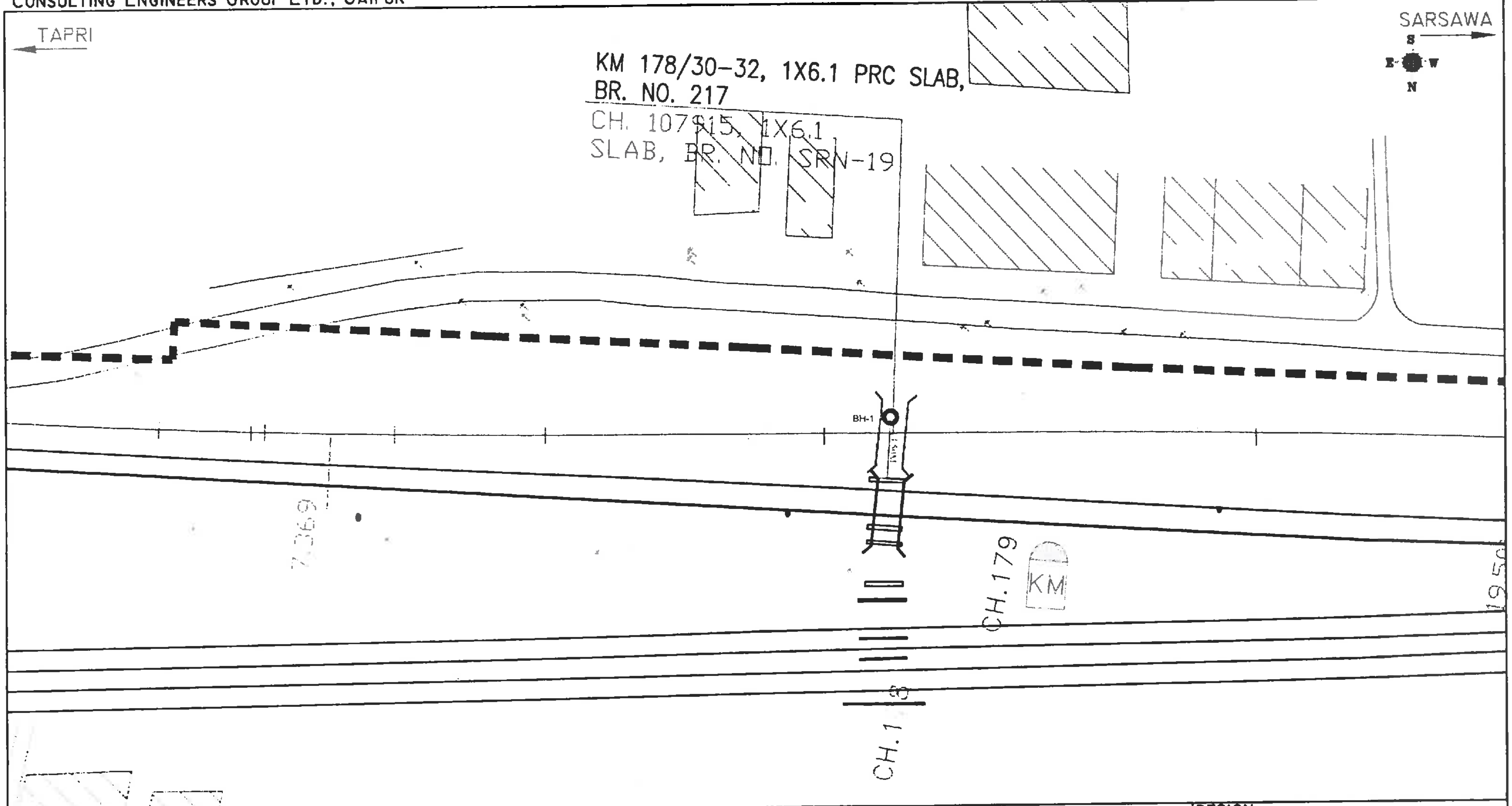
10.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

10.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 178/30/32	RL OF BH-I =274.393	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax. 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 217 AT CHAINAGE 178/30-32

Project :	Chainage 178/30-31 Bridge No. 217	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		27.12.2009 to 27.12.2009	1	1	07.50 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Clay	Silt	Sand Fine	Sand Medium	Sand Coarse	Gravel Fine	Gravel Coarse	L.L.	P.L.	P.I	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength c kg/cm²	Shear Strength ϕ degree
0.00	-	-	-	Silty Sand	3.68	20.28	63.25	10.52	0.65	1.62	0.00	25	NIL	NP	-	-	-	-	-	-
0.40	DS	-	-	Silty Sand	3.45	19.99	62.42	12.36	0.52	1.26	0.00	23	NIL	NP	-	-	-	-	-	-
1.50	8	1.43	11.44	Silty Sand	3.15	29.47	56.22	9.33	0.35	1.48	0.00	22	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	4.62	8.37	73.68	13.33	0.00	0.00	0.00	29	NIL	NP	1.70	10.36	1.54	2.67	0.00	28.0
4.50	12	1.07	12.84	Silty Sand	4.56	11.49	60.10	23.85	0.00	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	4.12	42.74	35.69	16.64	0.36	0.45	0.00	26	NIL	NP	1.90	16.36	1.63	2.64	0.00	29.5
7.50	16	0.89	14.24	Silty Sand	3.98	12.51	68.31	14.84	0.03	0.33	0.00	28	NIL	NP	-	-	-	-	-	-
10.50	19	0.78	14.82	Silty Sand	0.00	8.50	63.15	28.23	0.12	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
12.00	23	0.73	15.90	Silty Sand	4.55	9.60	75.80	10.05	0.00	0.00	0.00	28	NIL	NP	-	-	-	-	-	-

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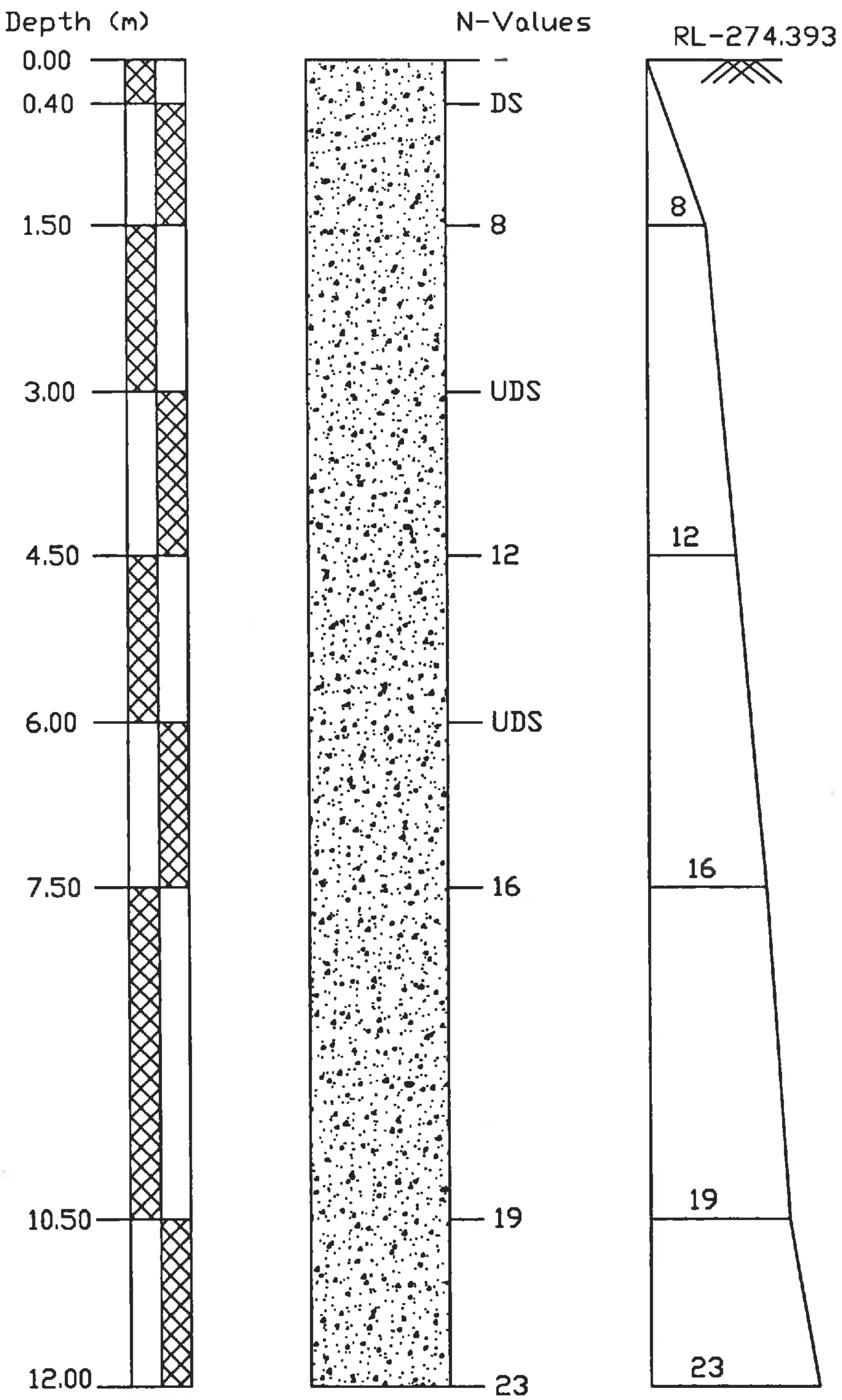
BORELOG OF BH–1 AT EXISTING KM–178/30–32 FOR MINOR BRIDGE NO.–217,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 178 30-32 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	26.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.73
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.80
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$q_d = c\, N_c\, s_c\, d_c\, i_c + q\, (N_q\text{-}1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$

The ultimate net bearing capacity in case of local shear failure is given by

$q'_d = (2/3)\, c\, N'_c\, s_c\, d_c\, i_c + q\, (N'_q\text{-}1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N'_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$

Where,

$d_c = 1 + 0.2\, (D_f/B)$*SQRT(N_ϕ)

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\, (D_f/B)$*SQRT($N_\phi$) for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Bearing capacity factors :

ϕ	26.00
N_c	22.60
N_q	12.21
N_γ	13.18

ϕ'	18.10
N'_c	13.36
N'_q	5.46
N'_γ	4.35

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.32	1.16	1.16
3	4.50	3.00	1.48	1.24	1.24
4	6.00	3.00	1.64	1.32	1.32

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	27.57	10.61	12.30
2	3.00	3.00	8.00	29.61	11.39	13.21
3	4.50	3.00	8.00	31.65	12.18	14.12
4	6.00	3.00	8.00	33.70	12.96	15.04

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

Location	Minor Bridge
Chainage	178/30-32
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	12.00
Average N value	13
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	30.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	21.8

Footing Depth (m)	3.00
SBC (t/m2)	13.00
Average N value	13
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	32.50
Depth Correction	0.83
Rigidity Factor	0.8
Corrected Settlement (mm)	21.6

Footing Depth (m)	4.50
SBC (t/m2)	14.00
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	30.80
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	18.2

Footing Depth (m)	6.00
SBC (t/m2)	15.00
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	33.00
Depth Correction	0.63
Rigidity Factor	0.8
Corrected Settlement (mm)	16.6

CHAPTER – 9

"Minor Bridge No. 218",

Location – Existing Km. – 179/04-05

9.1 LOCATION OF STRUCTURE:
Proposed Minor Bridge of Span 1x1.2x1.2

9.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***7.00m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 0.60	Sandy Silt	Loose
	0.60 to 7.50	Silty Sand	Loose
	7.50 to 12.00	Silty Sand	Medium Dense
	Below 12.00	Sandy Silt with Clay	Medium Dense

9.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.30	NIL	0.0024	NIL	0.0012	0.051
	12.00	8.60	0.005	0.0021	NIL	0.0012	0.049

9.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	12.00	15.00

9.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.0	66	120	129	659	0.4	4.5	801	1236
Requirement as per IS 456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

9.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	06.00
	3.00	07.50
	4.50	09.00
	6.00	10.50

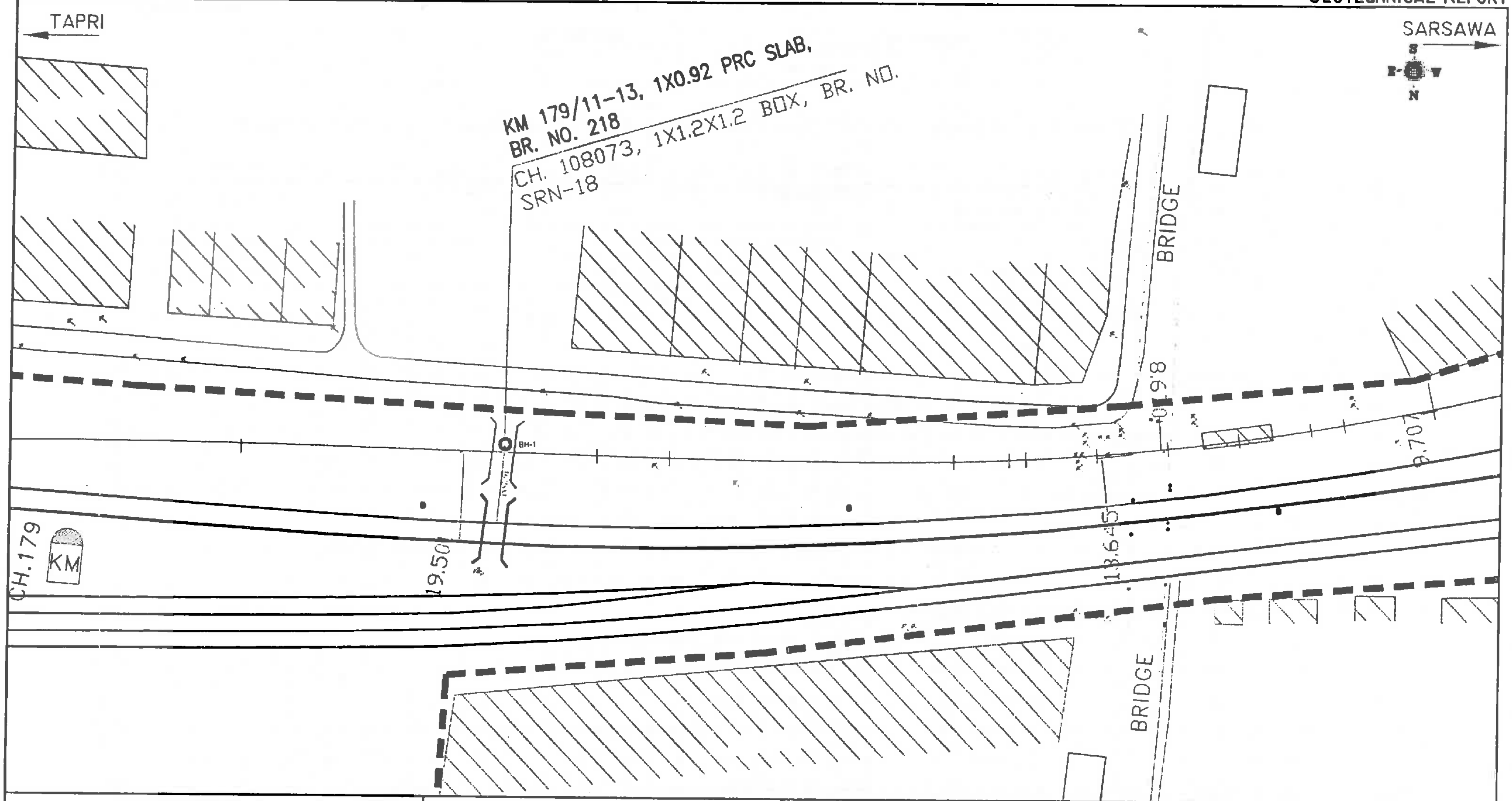
9.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

9.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 179/II/13	RL OF BH-I =274.593	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Maji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail. ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 218 AT CHAINAGE 179/11-13

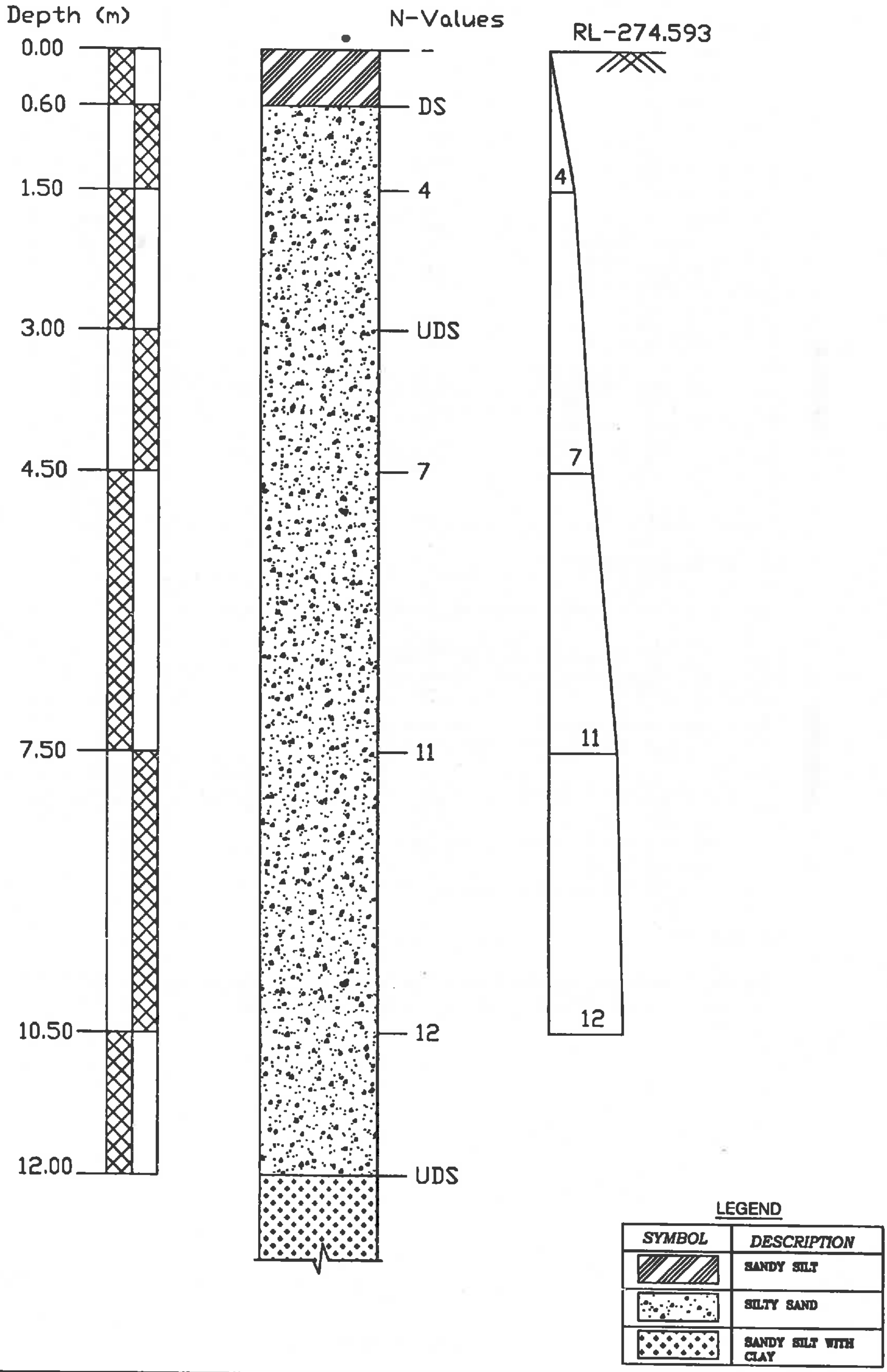
Project :	Chainage 179/04-05 Bridge No. 218	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		26.12.2009 to 26.12.2009	1	1	07.00 m.	12.00mtr	

Depth	Observ-	Correction	Corrected	Soil	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific	Shear Strength	
from	ed	Factor		Description	Clay	Silt	Sand			Gravel								Gravity	c kg/cm²	ϕ
GL (m)	N	C_n	N_n	(Soil Group)			Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Sandy Silt	2.36	9.04	70.15	18.45	0	0	0.00	24	NIL	NP	-	-	-	-	-	-
0.60	DS	-	-	Silty Sand	3.65	10.63	65.36	20.36	0	0	0.00	25	NIL	NP	-	-	-	-	-	-
1.50	4	1.45	5.80	Silty Sand	3.85	13.25	66.06	16.84	0.00	0.00	0.00	26	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	0.00	8.05	33.37	58.58	0.00	0.00	0.00	28	NIL	NP	1.71	9.94	1.55	2.67	0.00	28.0
4.50	7	1.08	7.56	Silty Sand	0.00	5.51	23.88	70.61	0.00	0.00	0.00	29	NIL	NP	-	-	-	-	-	-
7.50	11	0.91	10.01	Silty Sand	0.00	4.27	29.35	66.38	0.00	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
10.50	12	0.80	9.60	Silty Sand	0.00	6.08	39.64	52.05	1.03	1.20	0.00	29	NIL	NP	-	-	-	-	-	-
12.00	UDS	-	-	Sandy Silt with Clay	14.62	51.50	22.15	1.36	0.45	9.92	0.00	33	21	12	1.91	21.89	1.56	2.64	0.12	18.0

CONSULTING Engineers Group Ltd.

BORELOG OF BH–1 AT EXISTING KM–179/11–13 FOR MINOR BRIDGE NO.–218,

ON KESARI TO SANEHWAL, LUDHIANA



ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 179 11-13 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular 2

Angle of internal friction (ϕ °)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.72
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.75
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	1.20	8.00
2	3.00	1.20	8.00
3	4.50	1.20	8.00
4	6.00	1.20	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)*\mathrm{SQRT}(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*\mathrm{SQRT}(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	1.20	8.00	1.03	1.03	0.94
2	1.20	8.00	1.03	1.03	0.94
3	1.20	8.00	1.03	1.03	0.94
4	1.20	8.00	1.03	1.03	0.94

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	1.20	1.42	1.21	1.21
2	3.00	1.20	1.83	1.42	1.42
3	4.50	1.20	2.25	1.62	1.62
4	6.00	1.20	2.66	1.83	1.83

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	1.20	0.00	0.50
2	3.00	1.20	-1.25	0.50
3	4.50	1.20	-2.50	0.50
4	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	1.20	8.00	15.64	5.43	6.96
2	3.00	1.20	8.00	18.33	6.37	8.16
3	4.50	1.20	8.00	21.02	7.31	9.36
4	6.00	1.20	8.00	23.72	8.24	10.56

CONSULTING Engineers Group Ltd.

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	179 /4 -6
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	6.00
Average N value	7
Settlement for 10 t/m2 (mm)	64.00
Total Settlement (mm)	38.40
Depth Correction	0.8
Rigidity Factor	0.8
Corrected Settlement (mm)	**24.6**

Footing Depth (m)	3.00
SBC (t/m2)	7.50
Average N value	8
Settlement for 10 t/m2 (mm)	56.00
Total Settlement (mm)	42.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	**24.5**

Footing Depth (m)	4.50
SBC (t/m2)	9.00
Average N value	9
Settlement for 10 t/m2 (mm)	42.00
Total Settlement (mm)	37.80
Depth Correction	0.67
Rigidity Factor	0.8
Corrected Settlement (mm)	**20.3**

Footing Depth (m)	6.00
SBC (t/m2)	10.50
Average N value	9
Settlement for 10 t/m2 (mm)	42.00
Total Settlement (mm)	44.10
Depth Correction	0.67
Rigidity Factor	0.8
Corrected Settlement (mm)	**23.6**

CHAPTER – 8

"Minor Bridge No. 221A",

Location – Existing Km. – 182/00-01

CONSULTING Engineers Group Ltd.

8.1 **LOCATION OF STRUCTURE:**
Proposed Minor Bridge No. 221A

8.2 **BOREHOLE DESCRIPTIONS:**

(a) Location of Structure, Boreholes with RL shown in FIGURE-1.

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *8.50m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 3.00	Filled up Strata	Loose
	3.00 to 4.50	Silty Sand with Gravels	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

8.3 **CHEMICAL ANALYSIS OF SOIL:**

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.60	NIL	0.0026	NIL	0.0011	0.057
	9.00	8.80	NIL	0.0020	NIL	0.0011	0.049

8.4 **DIFFERENTIAL FREE SWELL INDEX (DFS)**

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	6.00	NIL
	9.00	NIL

8.5 **CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE**

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.5	79	142	113	669	0.4	3.9	792	1262
Requirement as per IS 456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

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8.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	3.00	12.00
	4.50	14.00
	6.00	16.00

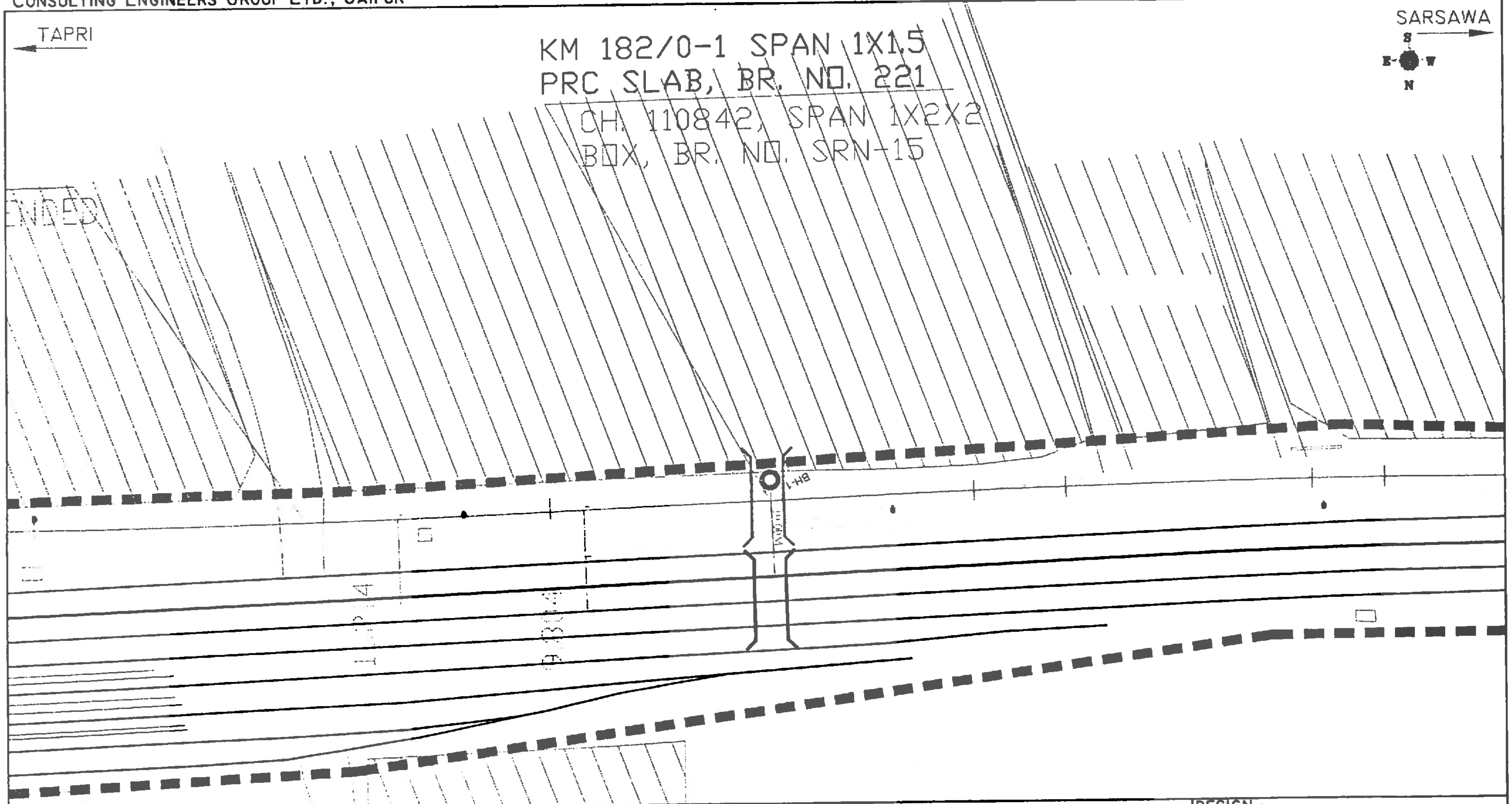
8.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

8.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 182/0-I	RL OF BH-I =274.433	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 221A AT CHAINAGE 182/00-01

Project :	Chainage 182/00-01 Bridge No. 221 A			Date of Testing	Location at		B.H. No.			Depth of Water Table		Termination Depth			Surface Elevation					
				25.12.2009 to 25.12.2009	1		1			08.50 m.		12.00mtr								
Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific Gravity	Shear Strength	
					Clay	Silt	Sand			Gravel										
							Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc		c kg/cm^2	ϕ degree
0.00	-	-	-	Filled up Strata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.00	DS	-	-	Silty Sand with Gravels	3.68	8.12	65.23	16.26	0.36	6.35	0.00	25	NIL	NP	-	-	-	-	-	-
4.50	12	1.07	12.84	Silty Sand	3.21	13.78	60.25	20.15	0.45	2.16	0.00	24	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	3.16	13.46	63.26	18.35	1.12	0.65	0.00	23	NIL	NP	1.81	11.52	1.62	2.67	0.00	28.0
7.50	19	0.90	17.10	Silty Sand	3.11	18.32	59.53	17.26	0.52	1.26	0.00	22	NIL	NP	-	-	-	-	-	-
9.00	UDS	-	-	Silty Sand	3.68	11.72	63.26	20.36	0.36	0.62	0.00	24	NIL	NP	1.88	19.35	1.58	2.64	0.00	29.0
10.50	21	0.78	15.69	Silty Sand	4.15	16.35	28.23	19.84	0.41	0.66	0.00	25	NIL	NP	-	-	-	-	-	-
12.00	26	0.74	17.12	Silty Sand	3.68	17.79	59.32	17.38	1.1	0.75	0.00	22	NIL	NP	-	-	-	-	-	-

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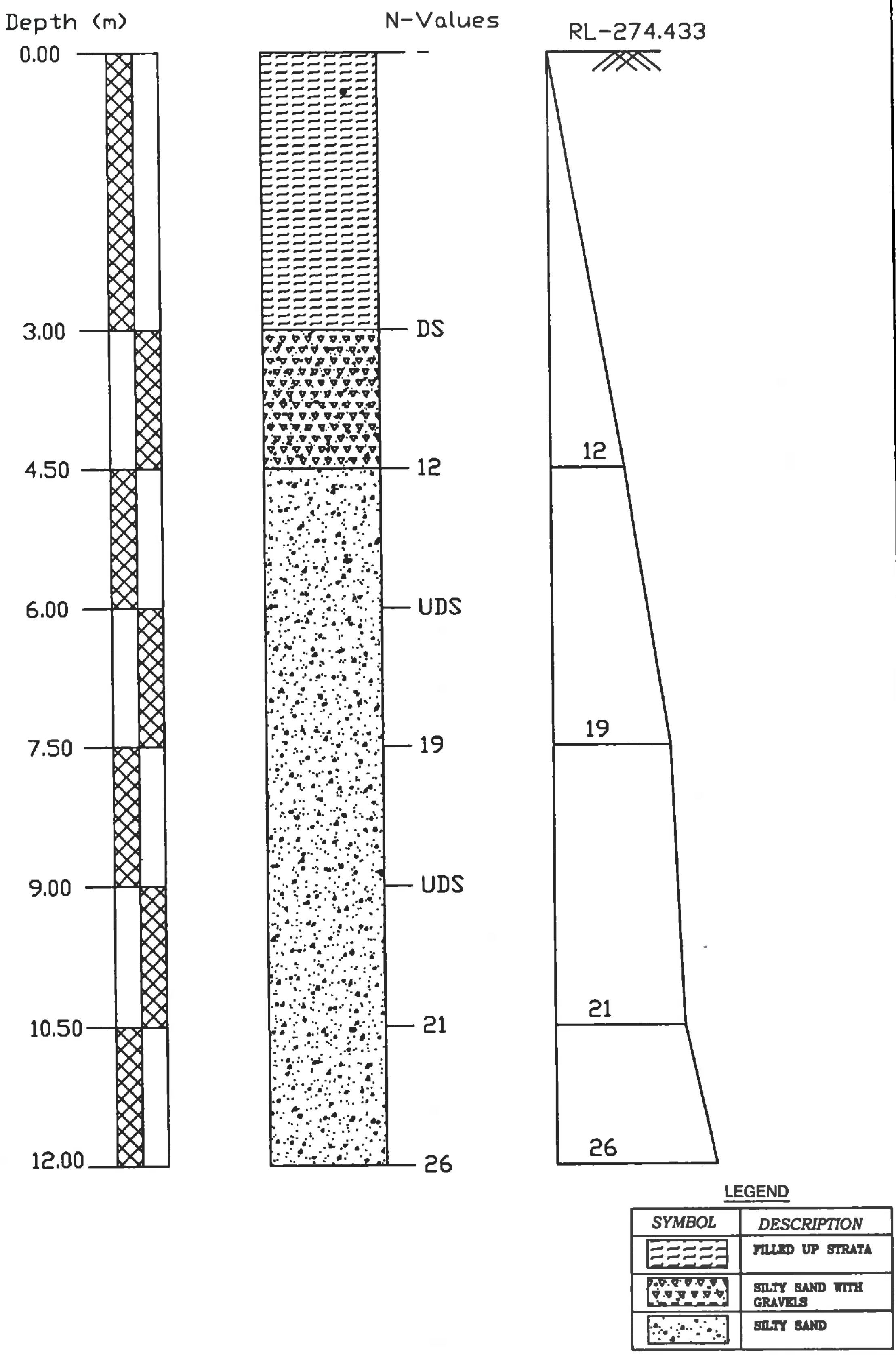
BORELOG OF BH–1 AT EXISTING KM–182/0–1 FOR MINOR BRIDGE NO.–221A,

ON KESARI TO SANEHWAL, LUDHIANA



ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 182 0-1 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular | 2

Angle of internal friction (ϕ °)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.65
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.81
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	3.00	1.20	8.00
2	4.50	1.20	8.00
3	6.00	1.20	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c s_c d_c i_c + q\,(N_q - 1)\, s_q d_q i_q + (1/2)\, B\, \gamma\, N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c s_c d_c i_c + q\,(N'_q - 1)\, s_q d_q i_q + (1/2)\, B\, \gamma\, N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B) * SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B) * SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	1.20	8.00	1.03	1.03	0.94
2	1.20	8.00	1.03	1.03	0.94
3	1.20	8.00	1.03	1.03	0.94

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	3.00	1.20	1.83	1.42	1.42
2	4.50	1.20	2.25	1.62	1.62
3	6.00	1.20	2.66	1.83	1.83

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	3.00	1.20	-1.25	0.50
2	4.50	1.20	-2.50	0.50
3	6.00	1.20	-3.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	3.00	1.20	8.00	18.47	6.41	12.44
2	4.50	1.20	8.00	21.19	7.35	14.27
3	6.00	1.20	8.00	23.90	8.30	16.10

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	182/00-01
Bore Hole No.	1

Footing Depth (m)	3.00
SBC (t/m2)	12.00
Average N value	13
Settlement for 10 t/m2 (mm)	20.00
Toatl Settlement (mm)	24.00
Depth Correction	0.74
Rigidity Factor	0.8
Corrected Settlement (mm)	14.2

Footing Depth (m)	4.50
SBC (t/m2)	14.00
Average N value	14
Settlement for 10 t/m2 (mm)	18.00
Toatl Settlement (mm)	25.20
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	13.7

Footing Depth (m)	6.00
SBC (t/m2)	16.00
Average N value	16
Settlement for 10 t/m2 (mm)	15.00
Toatl Settlement (mm)	24.00
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	13.1

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CHAPTER - 7

"Minor Bridge No. 223",

Location - Existing Km. - 182/27-29

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7.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span ***1x 3 x 3***

7.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***8.00m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 3.00	Silty Sand with Gravels	Loose
	3.00 to 4.50	Silty Sand	Loose
	4.50 to 12.00	Silty Sand	Medium Dense

7.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.10	NIL	0.0024	NIL	0.0018	0.026
	6.00	8.30	NIL	0.0026	NIL	0.0019	0.021

7.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

7.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.3	60	129	119	663	0.6	4.5	792	1236
Requirement as per IS 456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

7.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	10.00
	3.00	16.00
	4.50	16.50
	6.00	17.00

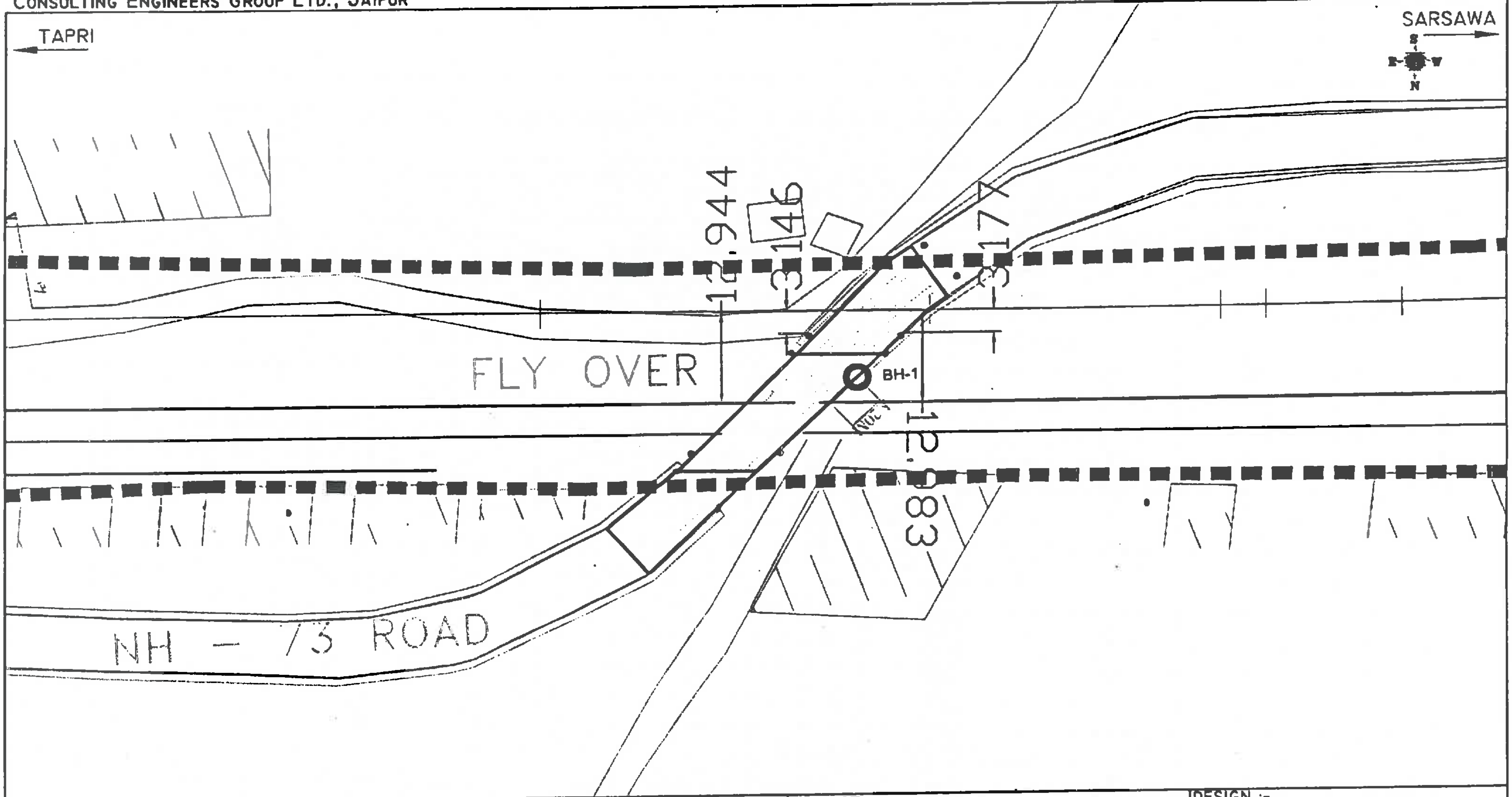
7.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

7.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 3.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 182/27-29	RL OF BH-I =276.683	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Maji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 223 AT CHAINAGE 182/27-29

Project :	Chainage 182/27-29 Bridge No. 223	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		24.12.2009 to 24.12.2009	1	1	08.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific Gravity	Shear Strength	
					Clay	Silt	Sand			Gravel										
							Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc		c kg/cm²	ϕ degree
0.00	-	-	-	Silty Sand with Gravels	3.26	13.10	60.25	15.68	0.56	7.15	0.00	23	NIL	NP	-	-	-	-	-	-
1.50	7	1.45	10.15	Silty Sand with Gravels	3.15	16.11	55.42	17.62	0.75	6.95	0.00	22	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	3.85	20.49	56.85	16.35	0	2.46	0.00	24	NIL	NP	1.76	11.69	1.58	2.67	0.00	27.0
4.50	12	1.08	12.96	Silty Sand	3.79	22.23	54.46	19.52	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	3.67	24.75	53.49	17.86	0.23	0.00	0.00	24	NIL	NP	1.86	15.23	1.61	2.65	0.00	29.0
7.50	13	0.90	11.70	Silty Sand	3.26	32.49	50.21	13.95	0.09	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
10.50	19	0.79	15.01	Silty Sand	3.86	30.62	51.70	13.63	0.19	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
12.00	23	0.74	16.01	Silty Sand	4.12	20.33	53.31	22.15	0.09	0.00	0.00	25	NIL	NP	-	-	-	-	-	-

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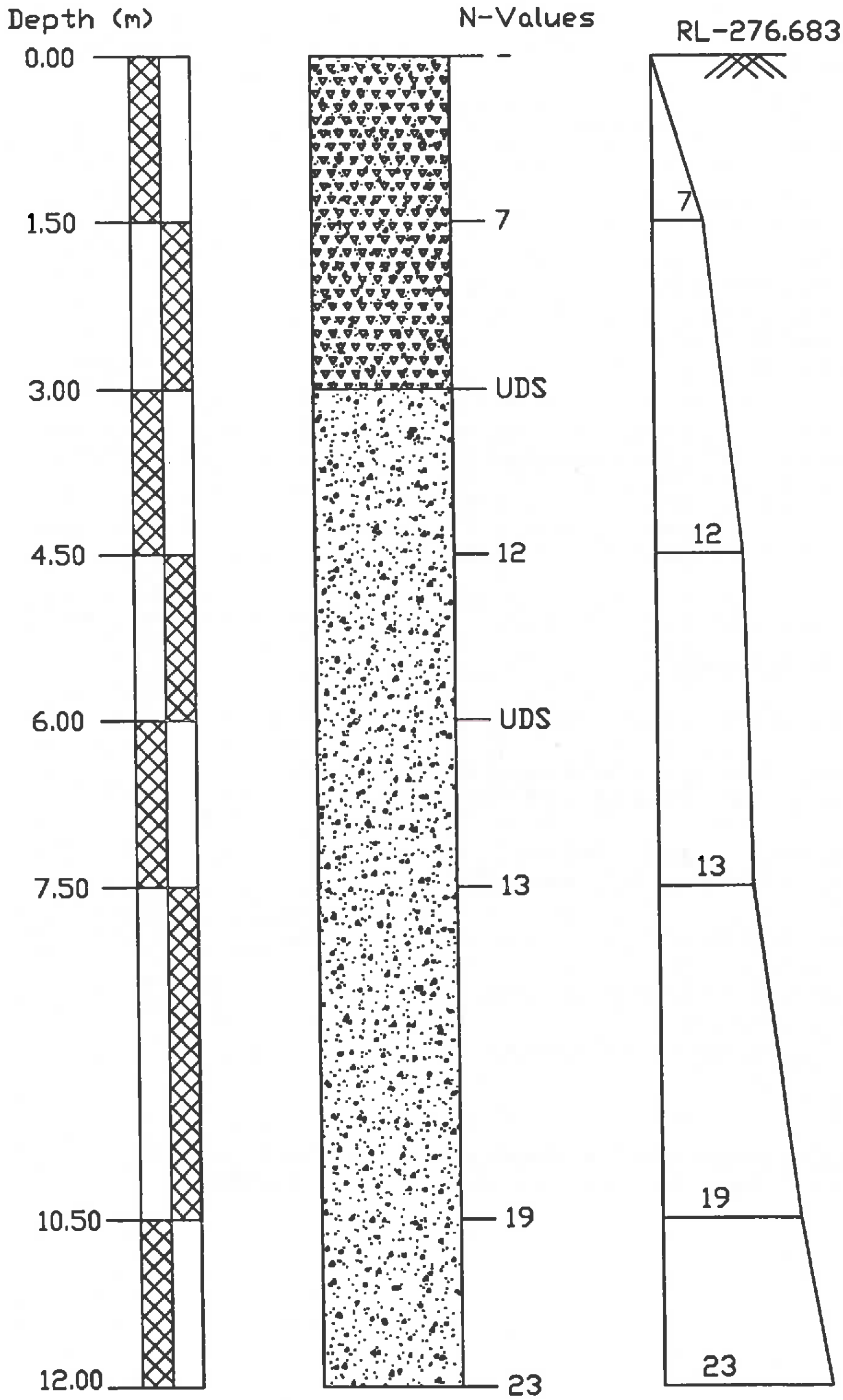
BORELOG OF BH–1 AT EXISTING KM–182/27–29 FOR MINOR BRIDGE NO.–223, ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND WITH GRAVELS
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 182 27-29 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular 2

Angle of internal friction (ϕ °)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.69
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.76
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00
3	4.50	3.00	8.00
4	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c s_c d_c i_c + q\,(N_q-1)\, s_q d_q i_q + (1/2)\, B \gamma N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c s_c d_c i_c + q\,(N'_q-1)\, s_q d_q i_q + (1/2)\, B \gamma N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)^*\mathrm{SQRT}(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^0$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)^*\mathrm{SQRT}(N_\phi)$ for $\phi > 10^0$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85
3	3.00	8.00	1.08	1.08	0.85
4	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.16	1.08	1.08
2	3.00	3.00	1.33	1.16	1.16
3	4.50	3.00	1.49	1.24	1.24
4	6.00	3.00	1.65	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50
3	4.50	3.00	-1.00	0.50
4	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	31.48	11.48	17.48
2	3.00	3.00	8.00	33.85	12.35	18.80
3	4.50	3.00	8.00	36.23	13.21	20.12
4	6.00	3.00	8.00	38.60	14.08	21.44

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	182/27-29
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	10.00
Average N value	12
Settlement for 10 t/m2 (mm)	23.00
Total Settlement (mm)	23.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	16.7

Footing Depth (m)	3.00
SBC (t/m2)	16.00
Average N value	12
Settlement for 10 t/m2 (mm)	23.00
Total Settlement (mm)	36.80
Depth Correction	0.82
Rigidity Factor	0.8
Corrected Settlement (mm)	24.1

Footing Depth (m)	4.50
SBC (t/m2)	16.50
Average N value	13
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	41.25
Depth Correction	0.75
Rigidity Factor	0.8
Corrected Settlement (mm)	24.8

Footing Depth (m)	6.00
SBC (t/m2)	17.00
Average N value	13
Settlement for 10 t/m2 (mm)	25.00
Total Settlement (mm)	42.50
Depth Correction	0.68
Rigidity Factor	0.8
Corrected Settlement (mm)	23.1

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CHAPTER - 6

"Minor Bridge No. 226",

Location - Existing Km. - 183/27-184/3

6.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span *1x 2 x 2*

6.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***7.00m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 3.00	Silty Sand	Loose
	3.00 to 4.50	Sandy Silt with Clay	Loose
	4.50 to 12.00	Sandy Silt with Clay	Medium Dense

6.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	7.80	NIL	0.0020	NIL	0.0011	0.011
	6.00	8.20	NIL	0.0016	NIL	0.0011	0.013

6.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	13.00
	6.00	13.00

6.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (μS/cm)
Test Result	7.1	73	143	128	673	0.3	2.6	812	1265
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

6.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	08.00
	3.00	09.50
	4.50	11.00
	6.00	12.00

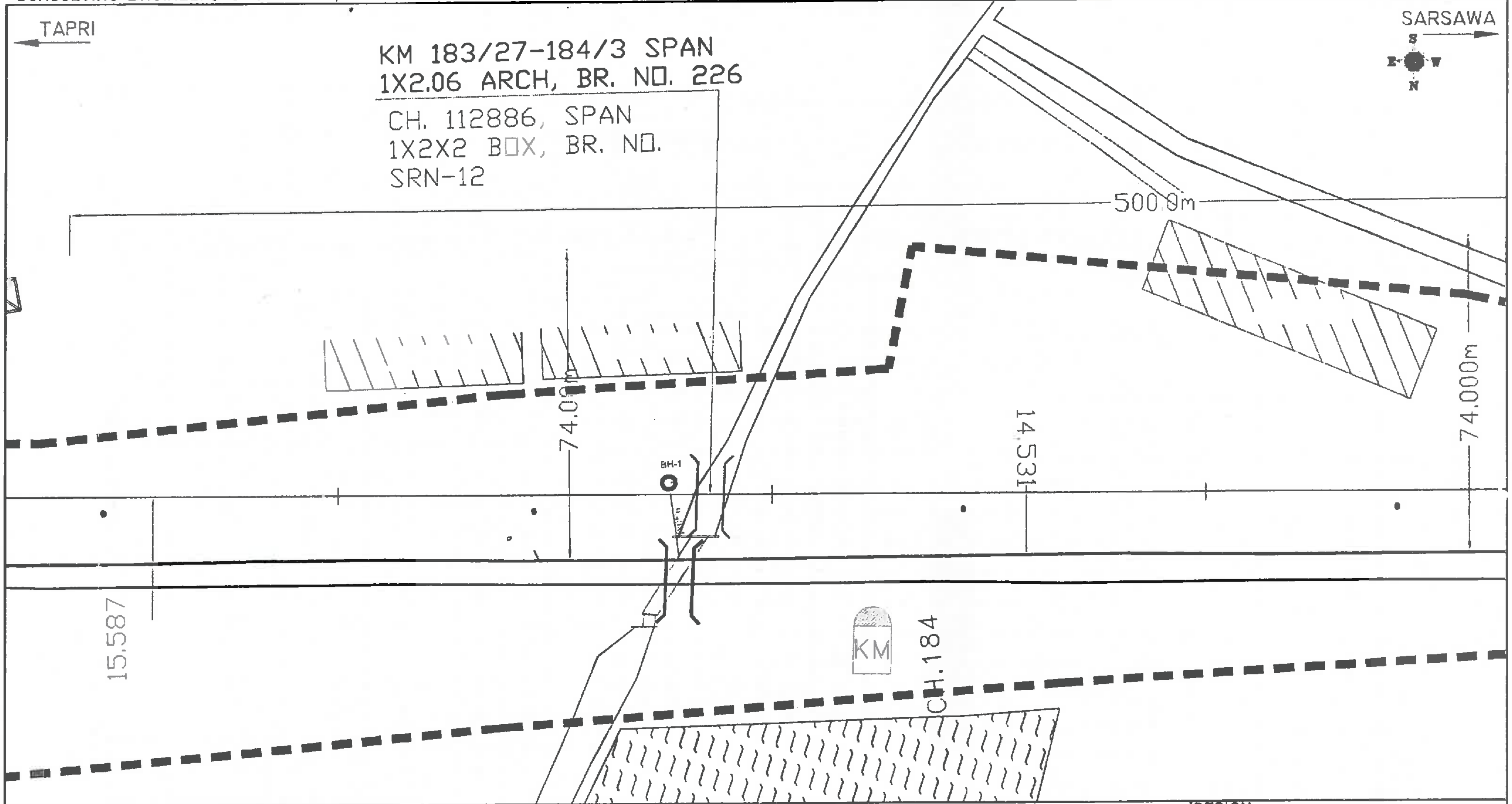
6.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

6.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED MINOR BRIDGE
AT CH. 183/27-184/3

RL OF BH-I =275.623

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-
CONSULTING
ENGINEERS GROUP LTD.
E-12,Moji Colony,Malviya Nagar Jaipur-17
Tel: +91-141- 2520899, 2521899, 2520556
Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 226 AT CHAINAGE 183/27-184/3

Project :	Chainage 183/27-184/3 Bridge No. 226	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		23.12.2009 to 23.12.2009	1	1	07.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Clay	Silt	Sand Fine	Sand Medium	Sand Coarse	Gravel Fine	Gravel Coarse	Atterberg Limits % L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength c kg/cm^2	ϕ degree
					Grain Size Distribution % wt retained															
0.00	-	-	-	Silty Sand	2.69	30.74	63.42	3.15	0.00	0.00	0.00	23	NIL	NP	-	-	-	-	-	-
1.50	9	1.43	12.87	Silty Sand	3.42	29.02	64.91	2.65	0.00	0.00	0.00	25	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Sandy Silt with Clay	10.65	67.74	16.35	2.16	0.95	2.15	0.00	31	22	9	1.76	13.26	1.55	2.64	0.1	20.0
4.50	14	1.07	14.98	Sandy Silt with Clay	9.42	73.70	10.66	1.07	0.79	4.36	0.00	31	23	8	-	-	-	-	-	-
6.00	UDS	-	-	Sandy Silt with Clay	10.85	65.05	20.34	2.16	0.36	1.24	0.00	32	23	9	1.92	18.42	1.62	2.62	0.11	19.0
7.50	19	0.89	15.96	Sandy Silt with Clay	7.63	65.37	23.37	3.46	0.17	0.00	0.00	28	21	7	-	-	-	-	-	-
10.50	22	0.77	15.97	Sandy Silt with Clay	10.00	73.72	14.85	1.12	0.31	0.00	0.00	29	20	9	-	-	-	-	-	-
12.00	26	0.73	16.99	Sandy Silt with Clay	6.68	80.15	12.17	1.00	0.00	0.00	0.00	28	22	6	-	-	-	-	-	-

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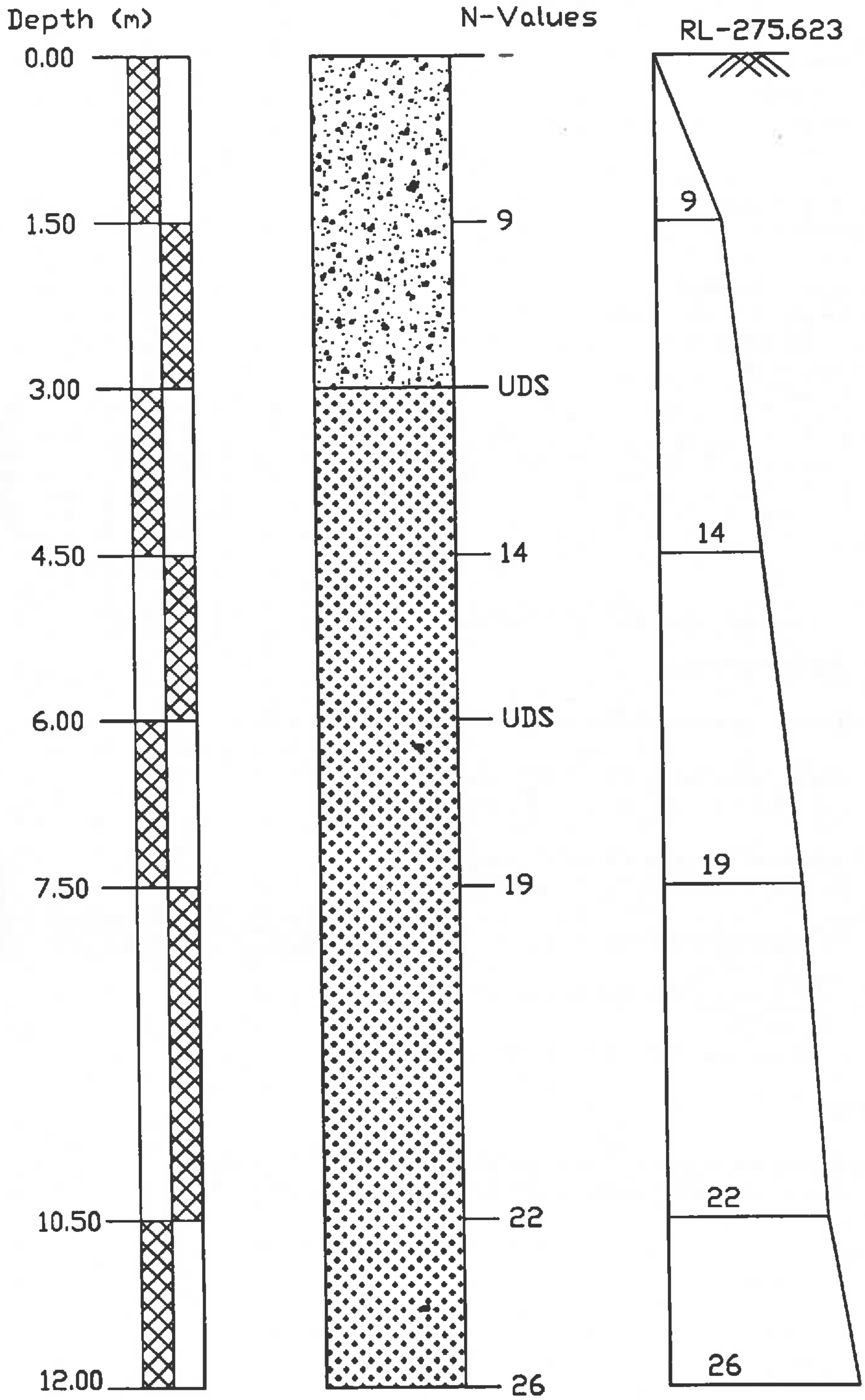
ANNEXURE-II

BORELOG OF BH–1 AT EXISTING KM–183/27–184/3 FOR MINOR BRIDGE NO.–226,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND
	SANDY SILT WITH CLAY

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 183 27- 184 3 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular 2

Angle of internal friction (ϕ °)	27.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.75
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.90
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

d_c = 1+ 0.2 (D_f/B)*SQRT(N_ϕ)

$d_q = d_\gamma$ = 1 for ϕ <10°

$d_q = d_\gamma$ = 1 + 0.1 (D_f/B)*SQRT(N_ϕ) for ϕ >10°

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 tanϕ)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

ANNEXURE - III

Bearing capacity factors :

ϕ	27.00
N_c	24.49
N_q	13.76
N_γ	15.49

ϕ'	18.85
N'_c	13.94
N'_q	5.83
N'_γ	4.76

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	2.00	8.00	1.05	1.05	0.90

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	2.00	1.24	1.12	1.12

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	2.00	0.00	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	2.00	8.00	21.99	7.98	7.98

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 183 27- 184 3 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular 2

Angle of internal friction (ϕ °)	19.00
Cohesion (c in t/m2)	1.10
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.90
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	3.00	2.00	8.00
2	4.50	2.00	8.00
3	6.00	2.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c\, s_c\, d_c\, i_c + q\,(N_q - 1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c\, s_c\, d_c\, i_c + q\,(N'_q - 1)\, s_q\, d_q\, i_q + (1/2)\, B\, \gamma\, N'_\gamma\, s_\gamma\, d_\gamma\, i_\gamma\, W'$$

Where,

$d_c = 1 + 0.2\ (D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^\circ$

$d_q = d_\gamma = 1 + 0.1\ (D_f/B)*SQRT(N_\phi)$ for $\phi > 10^\circ$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	19.00
N_c	14.06
N_q	5.91
N_γ	4.84

ϕ'	12.99
N'_c	9.92
N'_q	3.35
N'_γ	2.08

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90
3	2.00	8.00	1.05	1.05	0.90

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	3.00	2.00	1.42	1.21	1.21
2	4.50	2.00	1.63	1.32	1.32
3	6.00	2.00	1.84	1.42	1.42

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	3.00	2.00	-0.75	0.50
2	4.50	2.00	-1.50	0.50
3	6.00	2.00	-2.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	3.00	2.00	8.00	16.43	7.72	9.90
2	4.50	2.00	8.00	18.33	8.61	11.04
3	6.00	2.00	8.00	20.22	9.50	12.18

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	183/27- 184/3
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	8.00
Average N value	14
Settlement for 10 t/m2 (mm)	20.00
Settlement (mm) for SBC	16.00
Depth Correction	0.83
Corrected Settlement (mm)	13.3

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) — **Minor Bridge Ch. 183/27-184/3**

BH No. (A1)

Depth of foundation		=	3.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	2.0	m
Initial effective stress at mid of layer	Po	=	8.1	t/m^2
Concentrated load *P*		=	9.50	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.0	t/m^2
Compression Index	Cc	=	0.14	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_0	=	0.75	

$$\frac{Po + \Delta p}{Po} = 1.246296296$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.022949113 m

= 22.9 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.75

D = Depth of Foundation

L/B = 4.00

Depth Factor = 0.78

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 14.3 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) — **Minor Bridge Ch. 183/27-184/3**

BH No. (A1)				
Depth of foundation		=	4.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	2.0	m
Initial effective stress at mid of layer	Po	=	11.4	t/m^2
Concentrated load *P*		=	11.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.21	
	ΔP	=	2.3	t/m^2
Compression Index	Cc	=	0.14	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.75	

$$\frac{Po + \Delta p}{Po} = 1.202631579$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

$$S_f = 0.019231825 \text{ m}$$

$$= 19.2 \text{ mm}$$

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/LB)^{0.5}$ = 0.89

D = Depth of Foundation

L/B = 4.00

Depth Factor = 0.74

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 11.4 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Minor Bridge Ch. 183/27-184/3**

BH No. (A1)

Depth of foundation		=	6.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	2.0	m
Initial effective stress at mid of layer	Po	=	14.25	t/m^2
Concentrated load *P*		=	12.00	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
		I_B =	0.21	
	ΔP	=	2.5	t/m^2
Compression Index	Cc	=	0.14	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.75	

$$\frac{Po + \Delta p}{Po} = 1.176842105$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

$$S_f = 0.016972368 \text{ m}$$

$$= 17.0 \text{ mm}$$

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/LB)^{\wedge 0.5}$ = 0.67

D = Depth of Foundation

L/B = 4.00

Depth Factor = 0.74

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = $S_f \times$ D.F.x R.F.

S_{f2} = 10.0 mm

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CHAPTER – 5

"Minor Bridge No. 227A",

Location – Existing Km. – 184/19-21

5.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span *1x 2 x 2*

5.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table ***7.00m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 4.50	Sandy Silt with Clay	Loose
	4.50 to 7.50	Sandy Silt with Clay	Medium Dense
	7.50 to 12.00	Clayey Silt with Sand & Gravels	Medium Dense

5.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.20	NIL	0.0021	NIL	0.0012	0.011
	6.00	8.40	NIL	0.0025	NIL	0.0011	0.015

5.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	11.00
	6.00	13.00

5.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	7.0	70	128	132	701	0.4	4.28	840	1352
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

5.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	08.00
	3.00	09.50
	4.50	10.50
	6.00	11.50

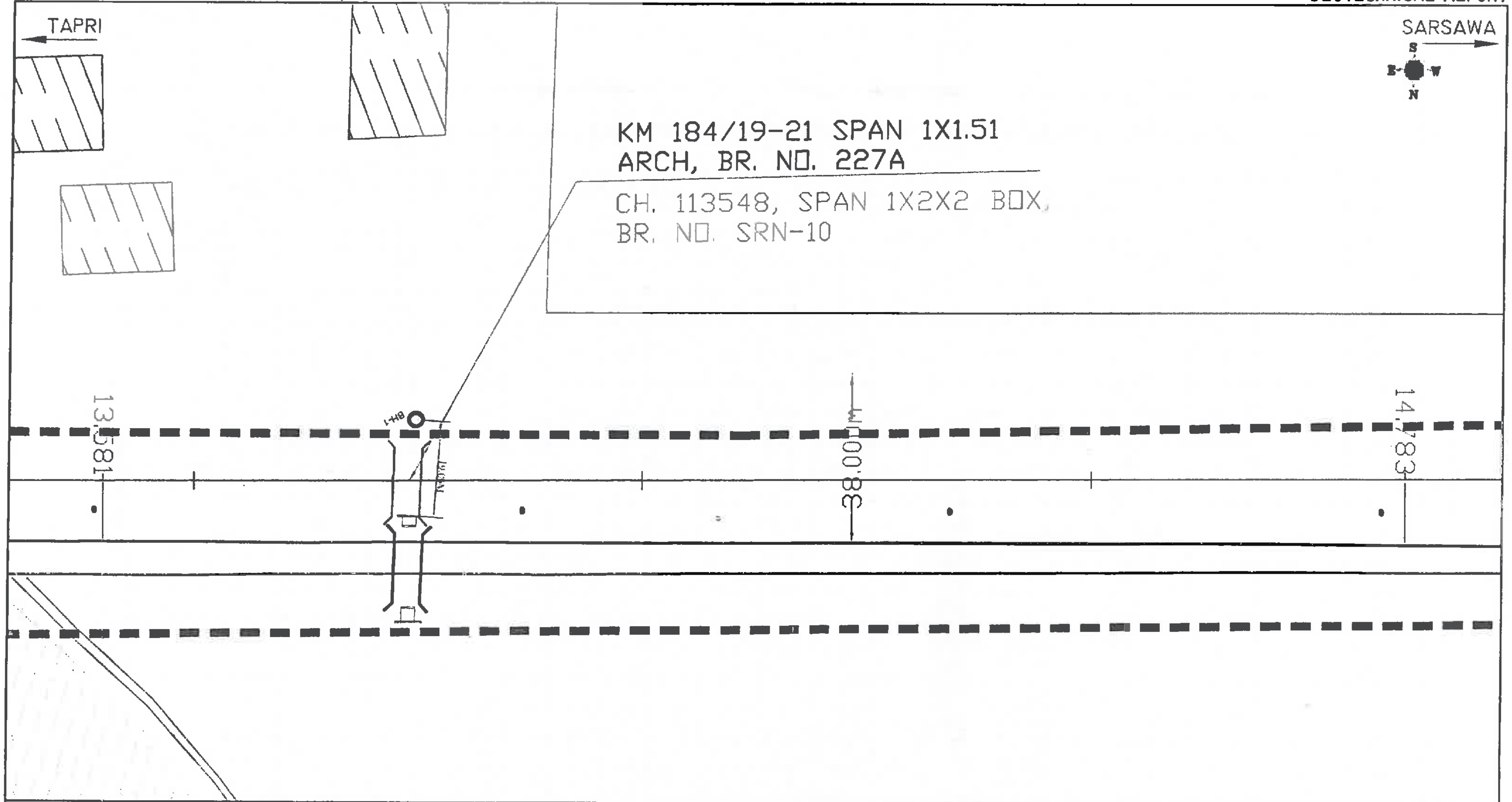
5.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

5.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER	RL OF BH-I =277.553	PROJECT :-	DESIGN :-
FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 184/19-21		LUDHIANA-AMBALA (DFCCIL)	CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel: +91-141- 2520899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 227 A AT CHAINAGE 184/19-21

Project :	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
Chainage 184/19-21 Bridge No. 227 A	23.12.2009 to 23.12.2009	1	1	07.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained							Atterberg Limits %			B.D.	M.C.	D.D.	Specific Gravity	Shear Strength	
					Clay	Silt	Sand			Gravel									c kg/cm^2	ϕ
							Fine	Medium	Coarse	Fine	Coarse	L.L.	P.L.	P.I.	gm/cc	%	gm/cc			degree
0.00	-	-	-	Sandy Silt with Clay	9.32	74.38	10.52	0.85	0.68	4.25	0.00	32	24	8	-	-	-	-	-	-
1.50	7	1.44	10.08	Sandy Silt with Clay	8.42	70.41	8.45	1.00	0.40	11.32	0.00	30	23	7	-	-	-	-	-	-
3.00	UDS	-	-	Sandy Silt with Clay	11.15	69.88	13.62	1.35	0.35	3.65	0.00	33	24	9	1.76	12.95	1.57	2.65	0.1	20.0
4.50	10	1.07	10.70	Sandy Silt with Clay	9.36	57.16	31.82	1.36	0.30	0.00	0.00	33	25	8	-	-	-	-	-	-
6.00	UDS	-	-	Sandy Silt with Clay	12.65	54.69	26.66	2.51	1.14	2.35	0.00	36	26	10	1.86	17.33	1.59	2.64	0.12	18.0
7.50	13	0.90	11.70	Clayey Silt with sand and Gravels	13.10	64.53	11.95	2.34	0.92	7.16	0.00	37	27	10	-	-	-	-	-	-
10.50	15	0.78	11.70	Clayey Silt with sand and Gravels	13.86	66.41	9.61	2.34	1.15	6.63	0.00	39	28	11	-	-	-	-	-	-
12.00	20	0.74	14.80	Clayey Silt with sand and Gravels	15.92	57.17	12.37	2.66	1.50	10.38	0.00	40	27	13	-	-	-	-	-	-

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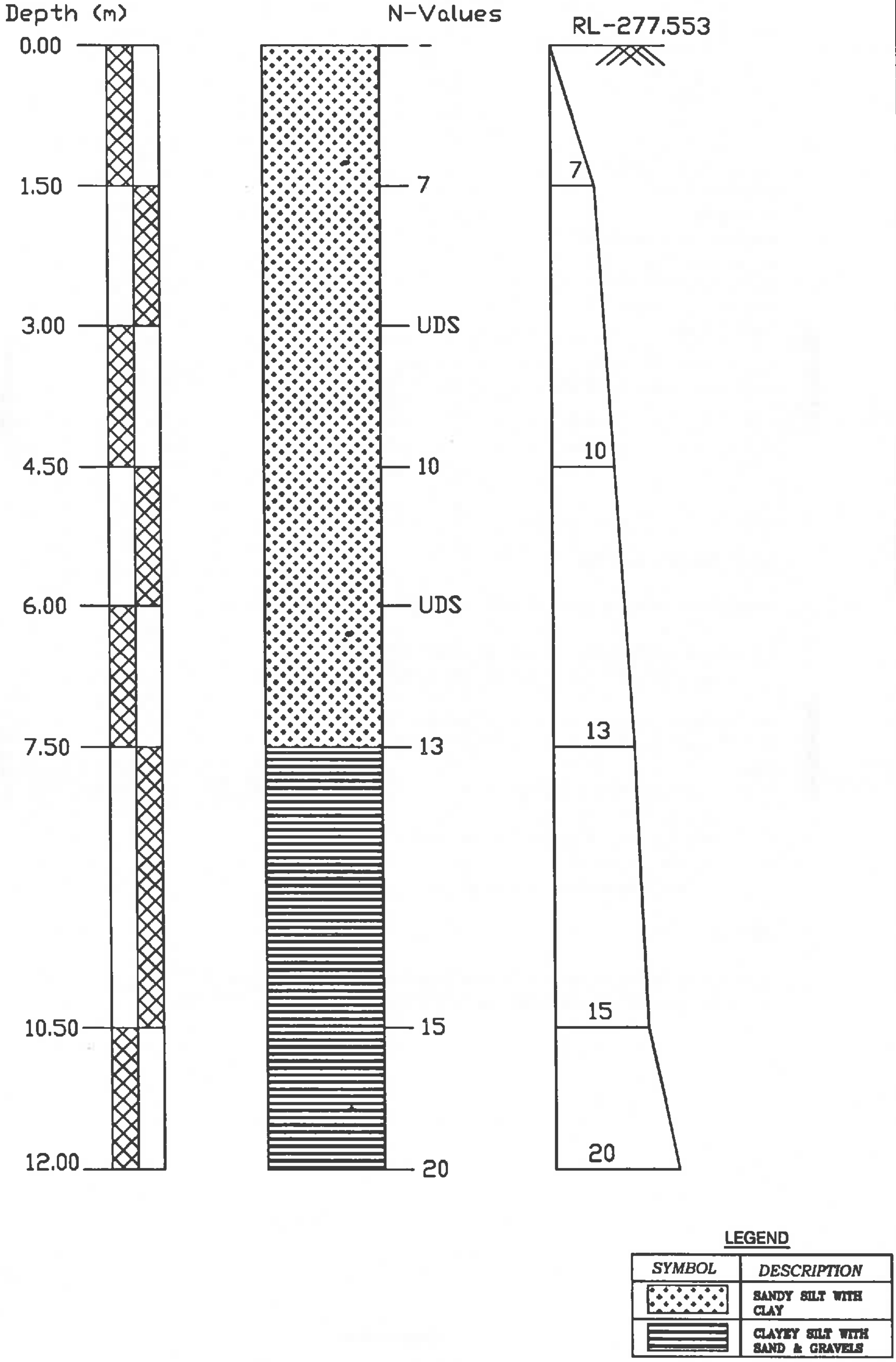
BORELOG OF BH–1 AT EXISTING KM–184/19–21 FOR MINOR BRIDGE NO.–221A, ON KESARI TO SANEHWAL, LUDHIANA



ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 184 19-21 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	18.00
Cohesion (c in t/m2)	1.20
Void ratio (e)	0.70
Direction of load with vertical (°)	0.00
Density of surcharge (t/m³)	1.70
Density of foundation soil (t/m³)	1.86
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00
2	3.00	2.00	8.00
3	4.50	2.00	8.00
4	6.00	2.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

$d_c = 1+ 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	18.00
N_c	13.29
N_q	5.42
N_γ	4.29

ϕ'	12.28
N'_c	9.55
N'_q	3.14
N'_γ	1.87

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90
3	2.00	8.00	1.05	1.05	0.90
4	2.00	8.00	1.05	1.05	0.90

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	2.00	1.21	1.10	1.10
2	3.00	2.00	1.41	1.21	1.21
3	4.50	2.00	1.62	1.31	1.31
4	6.00	2.00	1.83	1.41	1.41

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	2.00	0.00	0.50
2	3.00	2.00	-0.75	0.50
3	4.50	2.00	-1.50	0.50
4	6.00	2.00	-2.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	2.00	8.00	13.85	6.61	8.42
2	3.00	2.00	8.00	15.67	7.48	9.53
3	4.50	2.00	8.00	17.49	8.35	10.64
4	6.00	2.00	8.00	19.31	9.22	11.74

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Minor Bridge Ch. 184/19-21**

BH No. (A1)

Depth of foundation		=	1.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	2.0	m
Initial effective stress at mid of lay	Po	=	5.4	t/m^2
Concentrated load *P*		=	8.00	t/m^2
Incerase in pressure at mid of laye	ΔP	=	$P \times I_B$	
	I_B	=	0.195	
	ΔP	=	1.6	t/m^2
Compression Index	Cc	=	0.117	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.7	

$$\frac{Po + \Delta p}{Po} = 1.2888889$$

Settlement of clay layer

$$S_f = \frac{Cc}{1+ eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

$$S_f = 0.0227563 \text{ m}$$

$$= 22.756255 \text{ mm}$$

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$$D/(LB)^{\wedge 0.5} = 0.38$$

D = Depth of Foundation

$$L/B = 4.00$$

Depth Factor = 0.83

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction = N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 15.1 mm

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Settlement Calculation As per IS 8009 (Part 1) **Minor Bridge Ch. 184/19-21**

BH No. (A1)

Depth of foundation		=	3.0	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	2.0	m
Initial effective stress at mid of layer	Po	=	8.1	t/m^2
Concentrated load *P*		=	9.50	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.195	
	ΔP	=	1.9	t/m^2
Compression Index	Cc	=	0.117	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.7	
	$\frac{Po + \Delta p}{Po}$	=	1.2287037	

Settlement of clay layer $S_f = \frac{Cc}{1 + eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$

S_f = 0.0184682 m

= 18.468209 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.75

D = Depth of Foundation

L/B = 4.00

Depth Factor = 0.78

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction = N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 11.5 mm

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Minor Bridge Ch. 184/19-21**

BH No. (A1)

Depth of foundation		=	4.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	2.0	m
Initial effective stress at mid of lay	Po	=	10.8	t/m^2
Concentrated load *P*		=	10.50	t/m^2
Incerase in pressure at mid of laye	ΔP	=	$P \times I_B$	
	I_B	=	0.195	
	ΔP	=	2.0	t/m^2
Compression Index	Cc	=	0.117	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.7	

$$\frac{Po + \Delta p}{Po} = 1.1895833$$

Settlement of clay layer

$$S_f = \frac{Cc}{1 + eo} \quad H \quad \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0155668 m

= 15.566823 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$LB)^{\wedge 0.5}/D$ = 0.89

D = Depth of Foundation

L/B = 4.00

Depth Factor = 0.74

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction = N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 9.2 mm

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CHAPTER - 4

"Minor Bridge No. 228",

Location - Existing Km. - 185/05-07

4.1 LOCATION OF STRUCTURE:
Proposed Minor Bridge of Span *1 x 2 x 2*

4.2 BOREHOLE DESCRIPTIONS:
(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**
(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*
(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*
(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*
(e) Calculations of Probable Settlement in *ANNEXURE-IV.*
(f) Depth of water Table ***5.00m*** below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 4.50	Sandy Silt with Clay	Loose
	4.50 to 6.00	Silty Sand	Medium Dense
	6.00 to 12.00	Sand	Medium Dense

4.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	7.90	NIL	0.0024	NIL	0.0012	0.009
	6.00	8.10	NIL	0.0019	NIL	0.0013	0.010

4.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	13.00
	6.00	NIL

4.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (µS/cm)
Test Result	6.7	69	123	132	873	0.2	3.2	1010	1563
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

4.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m^2)
BH-1	1.50	07.50
	3.00	08.50
	4.50	15.00
	6.00	17.00

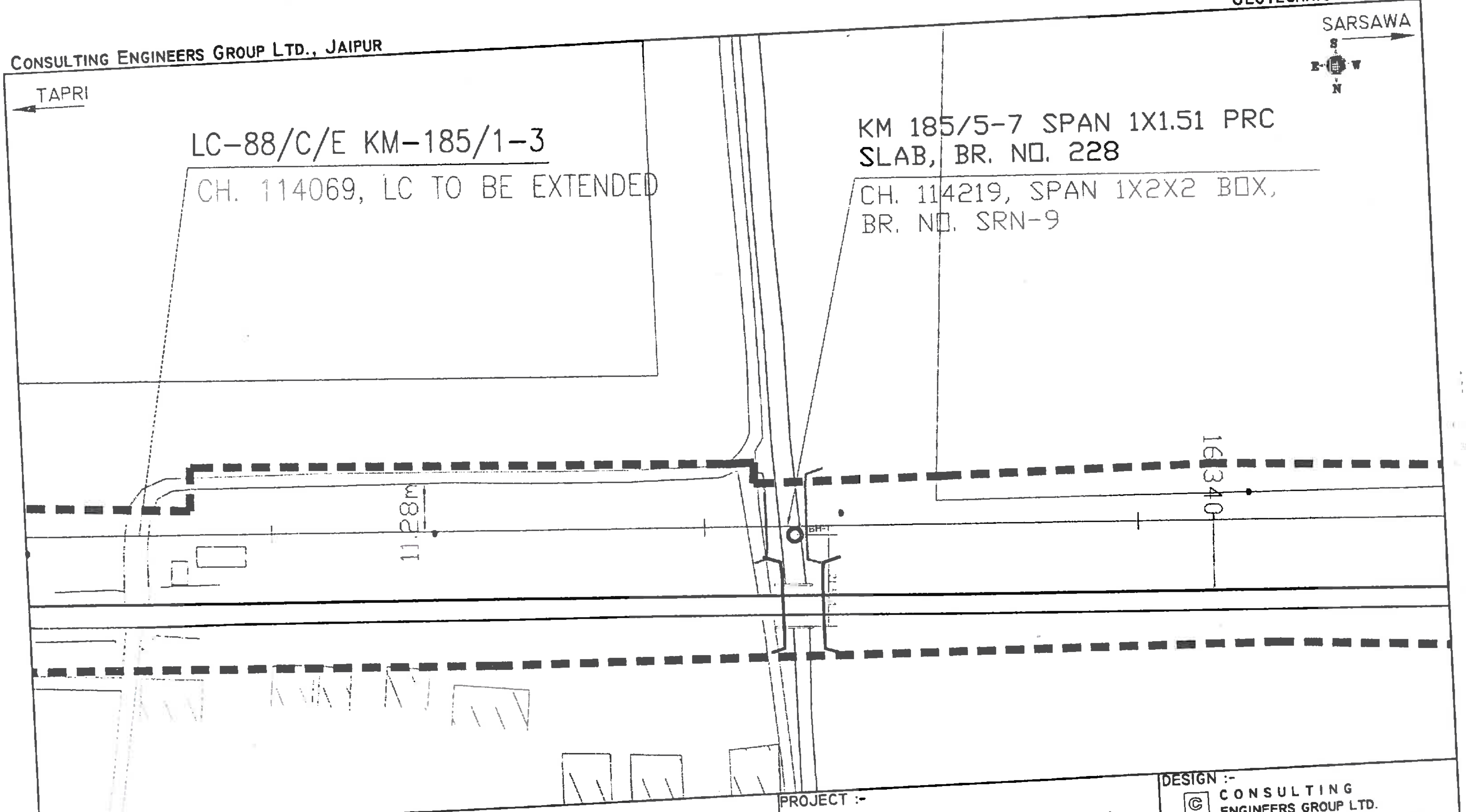
4.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

4.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open foundation
(ii)	*Depth of foundation below GL*	Below 4.50 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER

FIG.:-I
LOCATION PLAN OF PROPOSED MINOR BRIDGE
AT CH. 185/05-07

RL OF BH-I =278.603

PROJECT :-
LUDHIANA-AMBALA (DFCCIL)

DESIGN :-

CEG
CONSULTING
ENGINEERS GROUP LTD.
E-12,Moji Colony,Malviya Nagar Jaipur-17
Tel: +91-141- 2520899, 2521899, 2520556
Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 228 AT CHAINAGE 185/05-07

Project :	Chainage 185/05-07 Bridge No. 228	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
		23.12.2009 to 23.12.2009	1	1	05.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Grain Size Distribution % wt retained: Clay	Silt	Sand: Fine	Sand: Medium	Sand: Coarse	Gravel: Fine	Gravel: Coarse	Atterberg Limits %: L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength: c kg/cm^2	ϕ degree
0.00	-	-	-	Sandy Silt with Clay	12.14	50.96	18.65	10.25	6.35	1.65	0.00	31	21	10	-	-	-	-	-	-
1.50	9	1.44	12.96	Sandy Silt with Clay	9.65	52.10	21.16	8.87	7.12	1.10	0.00	29	21	8	-	-	-	-	-	-
3.00	UDS	-	-	Sandy Silt with Clay	11.68	50.64	19.62	10.47	6.34	1.25	0.00	30	20	10	1.72	12.94	1.52	2.65	0.11	20.0
4.50	11	1.07	11.77	Silty Sand	3.95	10.11	74.44	11.50	0.00	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Sand	0.00	2.39	57.62	39.64	0.35	0.00	0.00	23	NIL	NP	1.86	19.14	1.58	2.67	0.00	29.0
7.50	14	0.89	12.46	Sand	0.00	3.55	60.75	35.54	0.16	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
10.50	17	0.78	13.26	Sand	0.00	2.47	56.67	40.00	0.70	0.16	0.00	27	NIL	NP	-	-	-	-	-	-
12.00	21	0.74	15.27	Sand	0.00	3.96	29.83	65.50	0.71	0.00	0.00	30	NIL	NP	-	-	-	-	-	-

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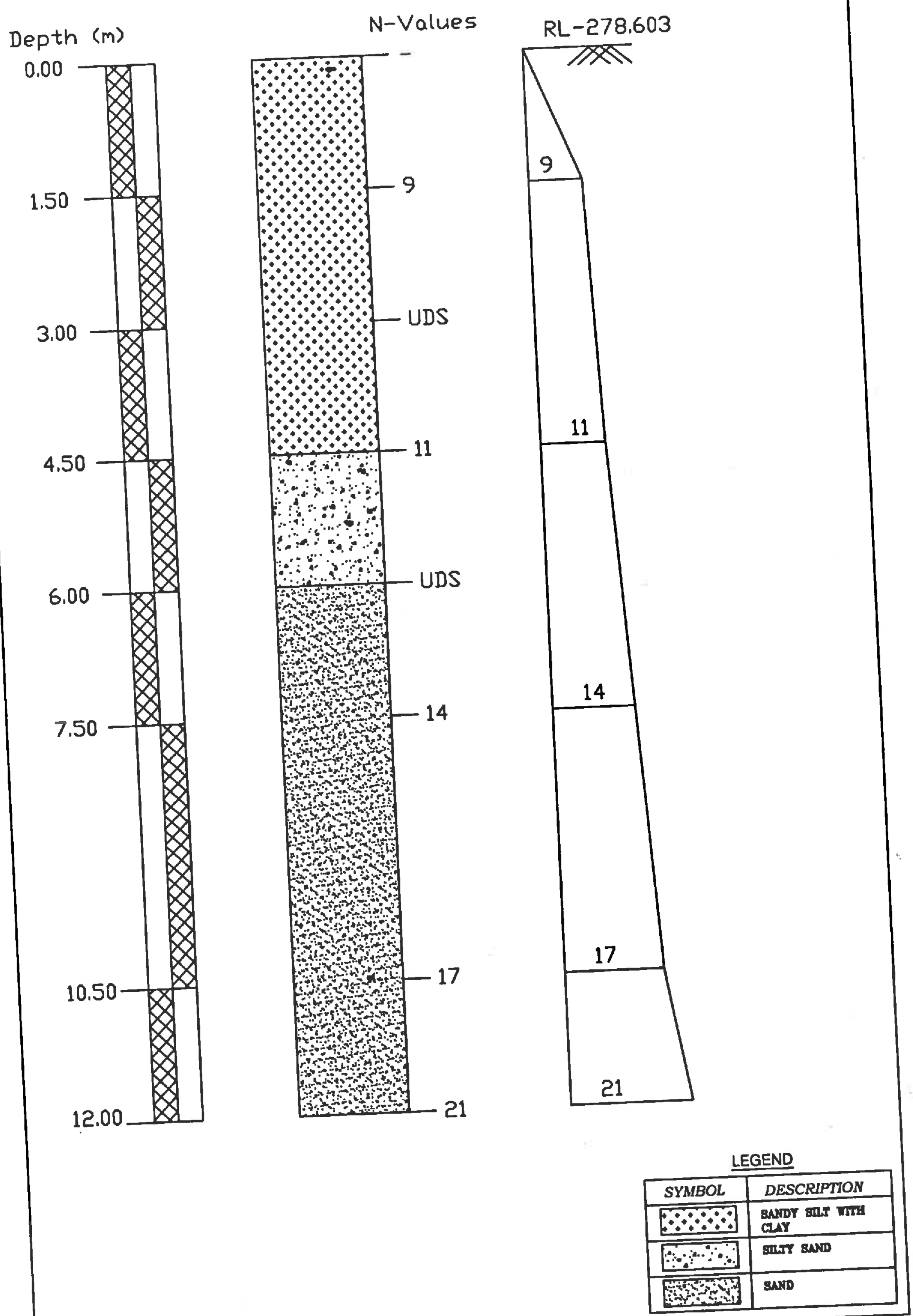
BORELOG OF BH–1 AT EXISTING KM–185/05–07 FOR MINOR BRIDGE NO.–228, ON KESARI TO SANEHWAL, LUDHIANA



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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 185 5-7 BH-1

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	20.00
Cohesion (c in t/m2)	1.10
Void ratio (e)	0.74
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.82
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	2.00	8.00
2	3.00	2.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$q_d = c\, N_c s_c d_c i_c + q\,(N_q - 1)\, s_q d_q i_q + (1/2)\, B\, \gamma\, N_\gamma s_\gamma d_\gamma i_\gamma W'$

The ultimate net bearing capacity in case of local shear failure is given by

$q'_d = (2/3)\, c\, N'_c s_c d_c i_c + q\,(N'_q - 1)\, s_q d_q i_q + (1/2)\, B\, \gamma\, N'_\gamma s_\gamma d_\gamma i_\gamma W'$

Where,

$d_c = 1 + 0.2\,(D_f/B)*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)*SQRT(N_\phi)$ for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

ANNEXURE - III

Bearing capacity factors :

ϕ	20.00
N_c	14.83
N_q	6.40
N_γ	5.39

ϕ'	13.70
N'_c	10.30
N'_q	3.56
N'_γ	2.28

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	2.00	1.21	1.11	1.11
2	3.00	2.00	1.43	1.21	1.21

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	2.00	0.00	0.50
2	3.00	2.00	-0.75	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	1.50	2.00	8.00	15.68	7.27	7.69
2	3.00	2.00	8.00	17.75	8.23	8.71

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 185 5-7 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	29.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.71
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.86
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	4.50	2.00	8.00
2	6.00	2.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\, N_c s_c d_c i_c + q\,(N_q-1)\, s_q d_q i_q + (1/2)\, B\, \gamma N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\, c\, N'_c s_c d_c i_c + q\,(N'_q-1)\, s_q d_q i_q + (1/2)\, B\, \gamma N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

d_c = 1+ 0.2 (D_f/B)*SQRT(N_ϕ)

$d_q = d_\gamma = 1$ for $\phi < 10°$

$d_q = d_\gamma = 1 + 0.1$ (D_f/B)*SQRT(N_ϕ) for $\phi > 10°$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

ANNEXURE - III

Bearing capacity factors :

ϕ	29.00
N_c	28.26
N_q	16.85
N_γ	20.10

ϕ'	20.37
N'_c	15.27
N'_q	6.72
N'_γ	5.80

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	2.00	8.00	1.05	1.05	0.90
2	2.00	8.00	1.05	1.05	0.90

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	4.50	2.00	1.76	1.38	1.38
2	6.00	2.00	2.02	1.51	1.51

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	4.50	2.00	-1.50	0.50
2	6.00	2.00	-2.25	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2)		
				General shear	Local shear	Actual
1	4.50	2.00	8.00	33.82	11.64	16.08
2	6.00	2.00	8.00	36.93	12.71	17.56

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Minor Bridge Ch. 185/05-07**

BH No. (A1)

Depth of foundation		=	1.5	m
Length of footing (L)		=	8.0	m
Width of footing (B)		=	2.0	m
Initial effective stress at mid of layer	Po	=	5.4	t/m^2
Concentrated load *P*		=	7.50	t/m^2
Incerase in pressure at mid of layer	ΔP	=	$P \times I_B$	
	I_B	=	0.195	
	ΔP	=	1.5	t/m^2
Compression Index	Cc	=	0.14	
Thickness of clay layer	H	=	3	m
Initial Void ratio	e_o	=	0.74	

$$\frac{Po + \Delta p}{Po} = 1.2708333$$

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0251248 m

= 25.124834 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{0.5}$ = 0.38

D = Depth of Foundation

L/B = 4.00

Depth Factor = 0.82

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= N.A.

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 16.5 mm

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1) **Minor Bridge Ch. 185/05-07**

BH No. (A1)

Depth of foundation = 3.0 m

Length of footing (L) = 8.0 m

Width of footing (B) = 2.0 m

Initial effective stress at mid of layer Po = 6.75 t/m^2

Concentrated load P = 8.50 t/m^2

Incerase in pressure at mid of layer ΔP = $P \times I_B$

I_B = 0.195

ΔP = 1.7 t/m^2

Compression Index Cc = 0.14

Thickness of clay layer H = 1.5 m

Initial Void ratio e_o = 0.74

$$\frac{Po + \Delta p}{Po} = 1.2455556$$

Settlement of clay layer

$$S_f = \frac{Cc}{1+eo} \; H \; \log_{10} \frac{Po + \Delta P}{Po}$$

S_f = 0.0115093 m

= 11.50934 mm

Correction for Depth and Rigidity of foundation on total settlement

Depth Factor Calculation

$D/(LB)^{\wedge 0.5}$ = 0.75

D = Depth of Foundation

L/B = 4.00

Depth Factor = 0.77

$$\text{Rigidity Factor} = \frac{\text{Total Settlement of Rigid foundation}}{\text{Total Settlement at the centre of Flexible foundation}}$$

= 0.8

Pore Pr. Correction= 0.85

Total Settlement = S_f x D.F.x R.F.

S_{f2} = 6.0 mm

Footing Depth (m)	3.00
SBC (t/m2)	1.70
Average N value	12
Settlement for 10 t/m2 (mm)	29.00
Total Settlement (mm)	4.93
Depth Correction	0.77
Rigidity Factor	0.8
Corrected Settlement (mm)	3.0

Total Settlement (mm)= 9.1

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ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)

Location	Minor Bridge
Chainage	185/05-07
Bore Hole No.	1

Footing Depth (m)	4.50
SBC (t/m2)	15.00
Average N value	13
Settlement for 10 t/m2 (mm)	27.00
Total Settlement (mm)	40.50
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	23.7

Footing Depth (m)	6.00
SBC (t/m2)	17.00
Average N value	14
Settlement for 10 t/m2 (mm)	22.00
Total Settlement (mm)	37.40
Depth Correction	0.7
Rigidity Factor	0.8
Corrected Settlement (mm)	20.9

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CHAPTER – 3

"Minor Bridge No. 231",

Location – Existing Km. – 186/17-19

CONSULTING Engineers Group Ltd.

3.1 LOCATION OF STRUCTURE:

Proposed Minor Bridge of Span *1 x 6.10*

3.2 BOREHOLE DESCRIPTIONS:

(a) Location of Structure, Boreholes with RL shown in **FIGURE-1.**

(b) Subsurface Characteristic of Soil/Rock shown in *ANNEXURE-I.*

(c) Borelogs and sub soil profile shown in *ANNEXURE-II.*

(d) Calculations of Safe Bearing Capacities in *ANNEXURE-III.*

(e) Calculations of Probable Settlement in *ANNEXURE-IV.*

(f) Depth of water Table *6.00m* below EGL.

Subsurface profile at the site

BOREHOLE No.	Depth (m)	Type of Soil/Rock	Soil/Rock Characteristics
BH-1	0.00 to 12.00	Silty Sand	Loose

3.3 CHEMICAL ANALYSIS OF SOIL:

BOREHOLE		CHEMICAL PROPERTIES					
No.	Depth (m)	pH	Carbonate	Chlorides %	Sulphate %	Nitrate %	Salinity %
BH-1	3.00	8.40	NIL	0.0016	NIL	0.0013	0.011
	6.00	8.30	NIL	0.0014	NIL	0.0011	0.009

3.4 DIFFERENTIAL FREE SWELL INDEX (DFS)

Bore Hole No.	Depth (m)	DFS Index in %
BH-1	3.00	NIL
	6.00	NIL

3.5 CHEMICAL ANALYSIS OF ENCOUNTERED WATER FROM BORE HOLE

Chemical Properties	pH Value	Chlorides mg/lit	Sulphate mg/lit	Organic Matter mg/lit	Inorganic Matter mg/lit	Acidity (ml)	Alkalinity (ml)	Total Disso. Solids (ppm)	Conductivity (μS/cm)
Test Result	6.9	65	135	126	682	0.3	4.80	816	1330
Requirement as per IS:456 / Morth's	Not less then 6.0	2000 for CC and 500 for RCC	400	200	3000	5 ml of 0.02 normal NaoH	25 ml of 0.02 normal H_2SO_4	-	-

3.6 NET ALLOWABLE BEARING PRESSURE

Borehole No.	Depth from EGL (m)	Net Allowable Bearing Pressure (t/m²)
BH-1	1.50	3.00
	3.00	6.00

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	4.50	9.50
	6.00	10.00

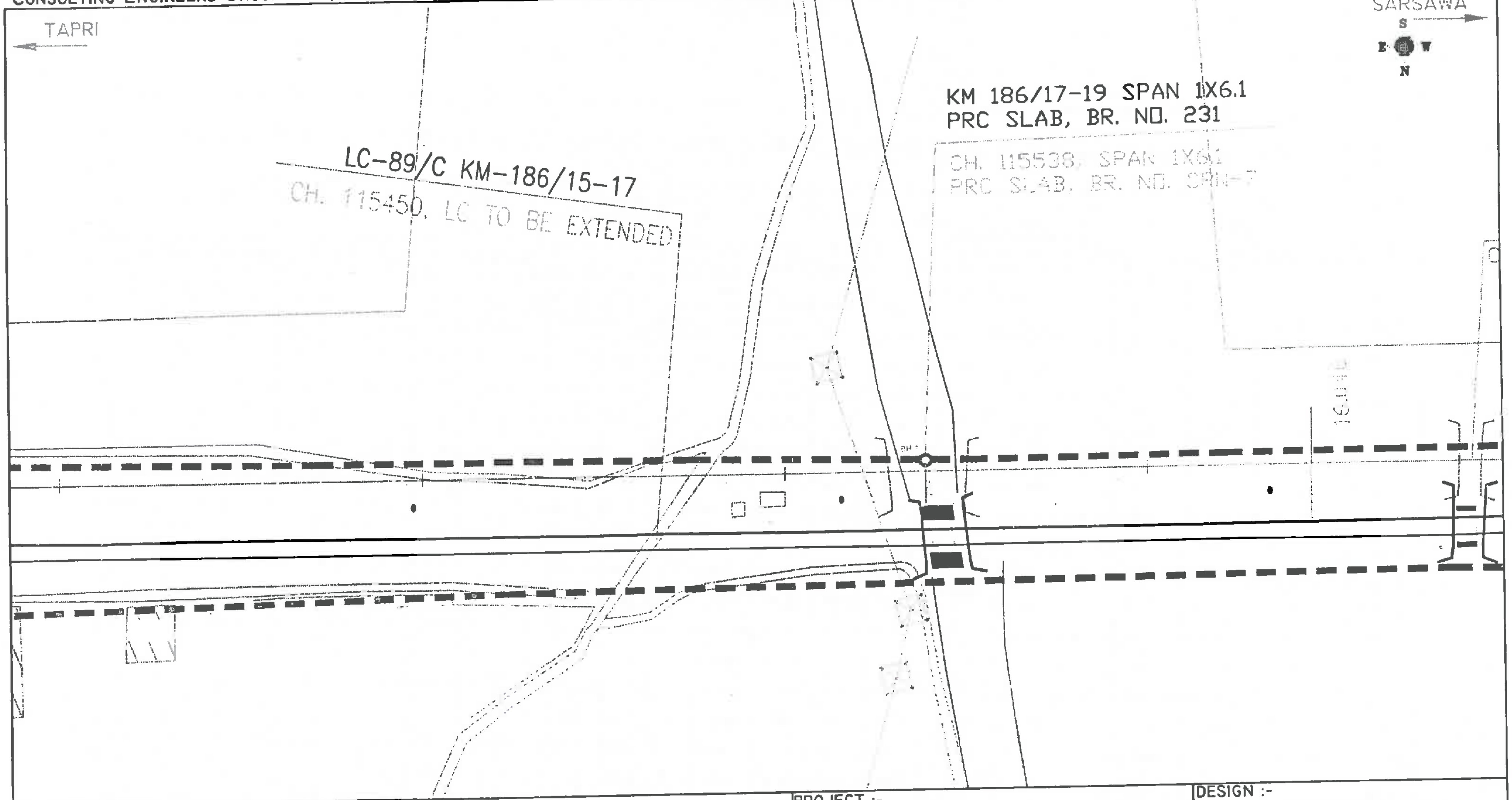
3.7 CONCLUSIONS

- Subsurface Profiles indicates suitable Soil formation for foundations.
- Chemical contents of Water are within the safe limits for construction purpose.

3.8 RECOMMENDATIONS

(i)	*Type of foundation*	Open and raft foundation
(ii)	*Depth of foundation below GL*	Below 6.00 m from EGL

Note- The above recommendations are based on the field and laboratory tests conducted on the soil, and our experience in this regard. If the actual subsoil conditions during excavation for the foundation differ from the observations reported here, the design experts/consultants should be referred for suggestion, further investigations. However, the Depth and Type of foundation is to be decided by the structure designer depending upon the type of loading/structure and site conditions.



ALL DIMENSIONS IN METER FIG.:-I LOCATION PLAN OF PROPOSED MINOR BRIDGE AT CH. 186/17-19	RL OF BH-I =276.603	PROJECT :- LUDHIANA-AMBALA (DFCCIL)	DESIGN :- CONSULTING ENGINEERS GROUP LTD. E-12,Moji Colony,Malviya Nagar Jaipur-17 Tel. +91-141- 2570899, 2521899, 2520556 Fax: 2521348, E-Mail: ceg@cegindia.com

ANNEXURE - I

SOIL CHARACTERISTICS OF BORE HOLE AT BH-1 FOR MINOR BRIDGE No. 231 AT CHAINAGE 186/17-19

Project :	Date of Testing	Location at	B.H. No.	Depth of Water Table	Termination Depth	Surface Elevation
Chainage 186/17-19 Bridge No. 231	21.12.2009 to 21.12.2009	1	1	06.00 m.	12.00mtr	

Depth from GL (m)	Observed N	Correction Factor C_n	Corrected N_n	Soil Description (Soil Group)	Clay	Silt	Sand Fine	Sand Medium	Sand Coarse	Gravel Fine	Gravel Coarse	Atterberg Limits % L.L.	P.L.	P.I.	B.D. gm/cc	M.C. %	D.D. gm/cc	Specific Gravity	Shear Strength c kg/cm²	Shear Strength φ degree
0.00	-	-	-	Silty Sand	3.14	9.02	62.65	23.67	1.52	0.00	0.00	27	NIL	NP	-	-	-	-	-	-
1.50	2	1.46	2.92	Silty Sand	4.12	5.44	66.44	22.97	1.03	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
3.00	UDS	-	-	Silty Sand	3.56	16.26	73.26	6.24	0.68	0.00	0.00	26	NIL	NP	1.69	8.26	1.56	2.65	0.00	29.0
4.50	5	1.09	5.45	Silty Sand	4.21	8.25	83.29	4.25	0.00	0.00	0.00	29	NIL	NP	-	-	-	-	-	-
6.00	UDS	-	-	Silty Sand	4.36	19.10	64.18	10.68	1.68	0.00	0.00	27	NIL	NP	1.73	16.15	1.49	2.62	0.00	28.0
7.50	8	0.92	7.36	Silty Sand	4.86	6.61	61.16	26.13	1.24	0.00	0.00	30	NIL	NP	-	-	-	-	-	-
10.50	9	0.81	7.29	Silty Sand	3.88	7.45	37.26	50.86	0.39	0.16	0.00	28	NIL	NP	-	-	-	-	-	-
12.00	13	0.76	9.88	Silty Sand	3.92	13.93	70.87	11.28	0.00	0.00	0.00	30	NIL	NP	-	-	-	-	-	-

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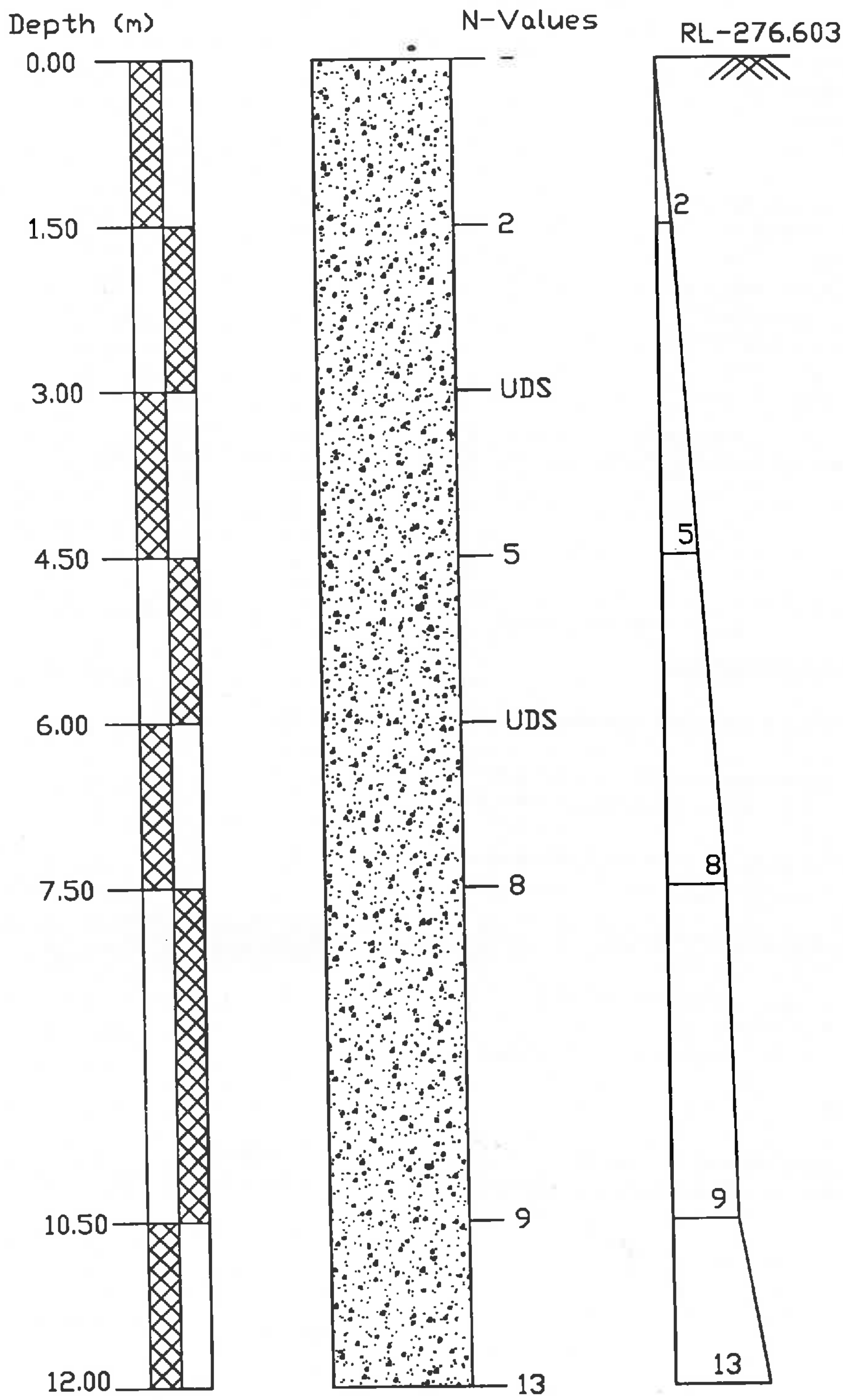
BORELOG OF BH–1 AT EXISTING KM–186/17–19 FOR MINOR BRIDGE NO.–231,

ON KESARI TO SANEHWAL, LUDHIANA



LEGEND

SYMBOL	DESCRIPTION
	SILTY SAND

ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 186 17-19 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ°)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.75
Direction of load with vertical ($^{\circ}$)	0.00
Density of surcharge (t/m^3)	1.69
Density of foundation soil (t/m^3)	1.69
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	1.50	3.00	8.00
2	3.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q-1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma\,s_\gamma\,d_\gamma\,i_\gamma\,W'$$

Where,

$d_c = 1 + 0.2\,(D_f/B)^*SQRT(N_\phi)$

$d_q = d_\gamma = 1$ for $\phi < 10^{\circ}$

$d_q = d_\gamma = 1 + 0.1\,(D_f/B)^*SQRT(N_\phi)$ for $\phi > 10^{\circ}$

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure $= \tan^{-1}(0.67 \tan\phi)$

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

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ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	1.50	3.00	1.17	1.08	1.08
2	3.00	3.00	1.33	1.17	1.17

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	1.50	3.00	0.00	0.50
2	3.00	3.00	-0.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m²)		
				General shear	Local shear	Actual
1	1.50	3.00	8.00	21.00	7.14	7.14
2	3.00	3.00	8.00	37.76	13.20	13.20

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ANNEXURE - III

Calculation of SBC for shallow foundations as per IS : 6403 - 1981

INPUT DATA

Ch 186 T7-19 **BH-1**

Type of footing

1 Continuous Strip
2 Rectangular
3 Square
4 Circular

Rectangular **2**

Angle of internal friction (ϕ °)	28.00
Cohesion (c in t/m2)	0.00
Void ratio (e)	0.75
Direction of load with vertical (°)	0.00
Density of surcharge (t/m^3)	1.70
Density of foundation soil (t/m^3)	1.73
Depth of water table(m)	1.50
Factor of safety	3.00

S.no.	Depth (m)	Width (m)	Length (m)
1	4.50	3.00	8.00
2	6.00	3.00	8.00

SHEAR FAILURE CRITERIA

Assumptions and formula used in calculation as per IS:6403-1981 are given below -

The ultimate net bearing capacity in case of general shear failure is given by

$$q_d = c\,N_c\,s_c\,d_c\,i_c + q\,(N_q\text{-}1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N_\gamma s_\gamma d_\gamma i_\gamma W'$$

The ultimate net bearing capacity in case of local shear failure is given by

$$q'_d = (2/3)\,c\,N'_c\,s_c\,d_c\,i_c + q\,(N'_q\text{-}1)\,s_q\,d_q\,i_q + (1/2)\,B\,\gamma\,N'_\gamma s_\gamma d_\gamma i_\gamma W'$$

Where,

d_c = 1+ 0.2 (D_f/B)*SQRT(N_ϕ)

$d_q = d_\gamma$ = 1 for ϕ <10°

$d_q = d_\gamma$ = 1 + 0.1 (D_f/B)*SQRT(N_ϕ) for ϕ >10°

$N_\phi = \tan^2(\pi/4 + \phi/2)$

ϕ' for local shear failure = $\tan^{-1}$ (0.67 $\tan\phi$)

OUTPUT

The computer aided results for shear failure criteria are tabulated below. The results are interpolated values of bearing capacity obtained from general and local shear failure criteria.

CONSULTING Engineers Group Ltd.

ANNEXURE - III

Bearing capacity factors :

ϕ	28.00
N_c	26.37
N_q	15.30
N_γ	17.79

ϕ'	19.61
N'_c	14.53
N'_q	6.21
N'_γ	5.18

Shape factors :

S.no.	Width(m)	Length (m)	S_c	S_q	S_γ
1	3.00	8.00	1.08	1.08	0.85
2	3.00	8.00	1.08	1.08	0.85

Depth factors :

S.no.	Depth(m)	Width(m)	dc	d_q	d_γ
1	4.50	3.00	1.50	1.25	1.25
2	6.00	3.00	1.67	1.33	1.33

Inclination factors :

$i_c = (1-\alpha/90)^2$	$i_q = (1-\alpha/90)^2$	$i_\gamma = (1-\alpha/\phi)^2$
1.00	1.00	1.00

Water table factor :

S.no.	Depth(m)	Width(m)	Z_w/B	W'
1	4.50	3.00	-1.00	0.50
2	6.00	3.00	-1.50	0.50

Safe Bearing Capacity

S.no.	Depth(m)	Width(m)	Length (m)	SBC in (t/m^2) General shear	Local shear	Actual
1	4.50	3.00	8.00	40.84	14.27	14.27
2	6.00	3.00	8.00	43.56	15.22	15.22

ANNEXURE - IV

Settlement Calculation As per IS 8009 (Part 1)	
Location	Minor Bridge
Chainage	186/17-19
Bore Hole No.	1

Footing Depth (m)	1.50
SBC (t/m2)	3.00
Average N value	5
Settlement for 10 t/m2 (mm)	160.00
Total Settlement (mm)	48.00
Depth Correction	0.91
Rigidity Factor	0.8
Corrected Settlement (mm)	34.9

Footing Depth (m)	3.00
SBC (t/m2)	6.00
Average N value	6
Settlement for 10 t/m2 (mm)	100.00
Total Settlement (mm)	60.00
Depth Correction	0.82
Rigidity Factor	0.8
Corrected Settlement (mm)	39.4

Footing Depth (m)	4.50
SBC (t/m2)	9.50
Average N value	7
Settlement for 10 t/m2 (mm)	68.00
Total Settlement (mm)	64.60
Depth Correction	0.75
Rigidity Factor	0.8
Corrected Settlement (mm)	38.8

Footing Depth (m)	6.00
SBC (t/m2)	10.00
Average N value	7
Settlement for 10 t/m2 (mm)	68.00
Total Settlement (mm)	68.00
Depth Correction	0.73
Rigidity Factor	0.8
Corrected Settlement (mm)	39.7

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Table 2.1: Laboratory Test Results on the Soil Samples Collected from CH (-)1600 Location																												
R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	φ (Deg.)	c (kN/m^2)	φ (Deg.)			
E.G.L-7.50	23	SS	Silty Clayey Fine Sand	9	-	-	-	-	2.67	-	19	-	-	M.Dense	0	0	0	83	12	5	-	-	8.0	30.3	-	-	SM
7.50-12.00	37	SS	Silty Fine Sand	7	-	-	-	-	2.67	-	15	-	-	Dense	0	0	0	79	14	7	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at Ch: (-) 1600				
Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(pp	Sulphates (pj
BH-01	7.50	7.83	128.32	102.43

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 CH: 1600 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 7.50m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	7.50m
SPT of the layer	24
Relative Density	Medium Dense
Angle of Shearing Resistance	33.90^{o}

* **Layer-2 (from 7.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	4.50m
SPT of the layer	38
Relative Density	Dense
Angle of Shearing Resistance	37.925^{o}

The ground water table was encountered at a depth of 7.80m within the explored depth of investigation in the fourth week of February 2009.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are coarse-grained type and can be considered as bearing strata for proposed impending loads form the superstructure**.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as coarse-grained soil strata can be considered as bearing strata.

The foundation system shall be located at a depth of 1.50m below the natural ground level (N.G.L). The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.

The safe bearing capacity of raft located at a depth of 1.50m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)

	(m)		
1	1.50	17	45

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths are coarse-grained type and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. The foundation system shall be located at a depth of 2.00m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.
4. **The safe bearing capacity of raft located at a depth of 2.00m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	1.50	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	1.50	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clayey Sand	
Least SPT-value of the Bearing Strata :	18	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	32.40	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	16.00	kN/m^3
Effective Overburden pressure at foundation level (q)	9.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:	
N_c =	N/A
N_q =	25.55
N_γ =	34.70
Shape Factors:	
S_c =	N/A
S_q =	1.30
S_γ =	1.00
Depth Factors :	
D_c =	N/A
D_q =	1.00
D_γ =	1.00
Inclination Factor:	
I_c =	N/A
I_q =	1.00
I_γ =	1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u =	437.77	kPa

2 Safe Bearing Capacity (Qsafe) :

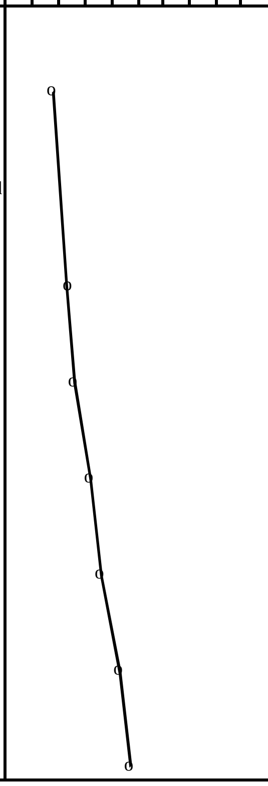
Factor of Safety (F.S.) :	2.50	
Qsafe :	175.11	kPa
Limited to an allowable bearing pressure per running meter width:	170.00	kPa

2 Settlements

Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 170kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 170kPa and SPT of 18 are computed to be in the order of 45mm which is within the permissible limits of 50mm for individual column footings and 70mm for rafts as per I.S:1904.

Project : Proposed Dedicated Freight Corridor at Khurja-Talheri at F1 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.
Location: At CH: (-)1600
Started On : 21/02/2009; Ended On : 21/02/2009 G.W.T: 7.80m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details: Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value	Graphical Representation of SPT (## 10 2(3(4(5(6(7(8(90)	Relative Density/Consistency	Type of Sample
			Brownish Medium Dense Silty Fine Sand	1.50	8	8	11	19		M.Dense	SS
				3.00	UDS Sampler Installed					M.Dense	UDS
				4.50	9	11	13	24		M.Dense	SS
				6.00	10	14	14	28		M.Dense	SS
7.50				7.50	12	15	17	32		Dense	SS
G.W.T			Brownish Medium Dense Silty Fine Sand	9.00	12	15	50	35		Dense	SS
				10.50	10	19	25	44		Dense	SS
12.00				12.00	11	20	27	47		Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at CH: (-)1600 Location

Table 2.1: Laboratory Test Results on the Soil Samples Collected from CH-(-)2356 Location

R.L of Sample below Existing Ground level(m)	SPT of Sample	Type of Sample	Visual & Engineering Classification of Soil	NMC(%)	Clay				Specific Gravity, G	Void Ratio, e	Bulk Density, kN/m^3	Free Swell (%)	Swelling Pressure (kPa)	Relative Density/ Consistency	Sieve Analysis						Triaxial Test		Box Shear		Unconfined Compression Tests, Cu (kPa)	Consolidation Tests, Cc	IS-Classification
					LL (%)	PL (%)	PI	Consistency, I_C							Gravel (%)	Coarse (%)	Medium (%)	Fine (%)	Silt (%)	Clay (%)	c (kN/m^2)	ϕ (Deg.)	c (kN/m^2)	ϕ (Deg.)			
E.G.L-3.50	8	SS	Silty Clayey Fine Sand	12	-	-	-	-	2.68	-	15	-	-	Loose	0	0	0	83	11	6	-	-	6.8	30.0	-	-	SM
3.50-12.00	22	SS	Silty Fine Sand	7	-	-	-	-	2.67	-	17	-	-	M.Dense	0	0	0	79	21	0	-	-	-	-	-	-	SM

Table 2.2: Chemical Analysis Results conducted on Water Sample collected from Bore Hole at CH-(-)2356

Location of Bore Hole	Depth of Sample below E.G.L. (m)	pH	Chlorides(ppm)	Sulphates (ppm)
BH-01	9.00	7.82	121.24	89.31

SUB-SURFACE STRATIFICATION

3.0 Preamble

The sub surface stratification at borehole locations, with respect to foundation/geotechnical engineering application are derived based on the visual identification, laboratory classification tests and field in-situ strength tests. Further, the strength parameters are estimated based on the in-situ strength test results as per the following correlation.

* **For Coarse Grained Samples, Ref. Fig.1, IS: 6403 to estimate Angle of Shearing Resistance.**
* **For Fine Grained Samples, Ref. Terzaghi & Peck, 1948, to estimate Unconfined Compressive Strength.**

3.1 Sub Surface Stratification:

3.1.1 Soil Profile at BH-01 Ch-2356 Location (As presented in the site plan)

* **Layer-1 (from E.G.L to 3.50m depth below)**

Type of Strata	Silty Clayey Fine Sand
Colour	Brownish
Thickness of Layer	3.50m
SPT of the layer	08
Relative Density	Loose
Angle of Shearing Resistance	29.60^{o}

* **Layer-2 (from 3.50m to 12.00m depth below)**

Type of Strata	Silty Fine Sand
Colour	Brownish
Thickness of Layer	8.50m
SPT of the layer	22
Relative Density	Medium Dense
Angle of Shearing Resistance	33.60^{o}

The ground water table was encountered at a depth of 8.20m within the explored depth of investigation in the fourth week of February 2009.

FOUNDATION SYSTEM

4.0 Preamble

The foundation system design is an interface between super structure and the sub soil bearing strata characteristics. A sound foundation system should be safe against bearing strata shear response under the super structure load intensity. Similarly, the stability of the foundation system is governed by the bearing strata deformation response under the super structure load intensity. In addition, as a combined system of super structure and foundation, the over all stability is also governed by the super structure arrangement.

Considering the above aspects of foundation design, the suitable type of foundation system with respect to the sub soil conditions encountered at the borehole location is presented in the subsequent sections.

4.1 Bearing Strata Characteristics:

From the investigation location, it can be observed that the sub-soil stratifications encountered at shallow depths are coarse-grained type and can be considered as bearing strata for proposed impending loads form the superstructure**.**

Considering the above, the suitable foundation system for the proposed structure is described below.

4.2 Foundation System

4.2.1 Open Foundation System

Considering the bearing strata characteristics presented above, it can be implicated that the sub-soil strata encountered immediately as coarse-grained soil strata can be considered as bearing strata.

The foundation system shall be located at a depth of 2.00m below the natural ground level (N.G.L). The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.

The safe bearing capacity of raft located at a depth of 2.00m below the natural ground level is presented below and can be adopted for foundation design purposes.

S.No.	Depth of Foundation System below N.G.L	Safe Bearing Capacity (t/m^2)	Elastic Settlements (mm)

	(m)		
1	2.00	11	48

Under the recommended safe bearing pressure, the settlements of the bearing strata will be of immediate elastic nature and computed to be within the permissible limits of 70mm for rafts as per revised I.S:1904.

The details of the computations are annexed to this report.

RECOMMENDATIONS

1. The sub-soil stratifications encountered at shallow depths are coarse-grained type and are good from both shear and deformation considerations to act as bearing strata for the proposed impending loads from the superstructure.
2. The foundation system shall be located at a depth of 2.00m below the natural ground level (N.G.L).
3. The safe bearing capacity of the foundation system will be a function of width of the footing and effective overburden pressure over the bearing strata.
4. **The safe bearing capacity of raft located at a depth of 2.00m below the natural ground level as presented in Clause 4.2.1 can be adopted for foundation design purposes.**
5. Under the recommended safe bearing pressure, the settlements will be of immediate elastic nature and are computed to be within the permissible limits of 70mm for rafts as per revised I.S: 1904.
6. The safe bearing capacity of the foundation system is computed considering any rise in the ground water table at or above the level of foundation system.
7. In case, the ground water table is encountered at shallow depths i.e. at or above the recommended depth of footing, provisions shall be made to bail the water out of the foundation trenches to keep them consolidated dry.
8. As the chlorides and sulphates present in the water sample are within the permissible limits, no special steel or cement is required for foundation construction purposes.

DESIGN OF OPEN FOUNDATION SYSTEM

1 COMPUTATION OF BEARING CAPACITY AS PER IS:6403

1 Geometrical Data :

Type of Footing:	Isolated Column	
Depth of foundation below the E.G.L:	2.00	m
Observed Maximum thickness of Filled up Soil:	0.00	m
Effective Depth of Foundation below E.G.L:	2.00	m
Minimum Width of Foundation (B):	1.00	m

1 Soil Data :

Type of Bearing Strata :	Silty Clayey Sand	
Least SPT-value of the Bearing Strata :	8	
Type of Shear Failure:	General	
Angle of Shearing Resistance, ϕ:	29.60	Deg.

1 Design Parameters:

Bulk Density of Soil above the foundation detph (γ_{bulk})	15.00	kN/m^3
Effective Overburden pressure at foundation level (q)	10.00	kPa
Water Table Correction Factor (w')	0.50	

Bearing Capacity Factors:

N_c = N/A

N_q = 17.78

N_γ = 21.48

Shape Factors:

S_c = N/A

S_q = 1.30

S_γ = 1.00

Depth Factors :

D_c = N/A

D_q = 1.00

D_γ = 1.00

Inclination Factor:

I_c = N/A

I_q = 1.00

I_γ = 1.00

1 Ultimate Bearing Capacity (Qu) :

$Qu = Cu*Nc*Sc*D_C*I_C+q*(Nq-1)*Sq*Dq*Iq + 0.5*B*\gamma*N\gamma*S\gamma*D\gamma*Ig*w'$

Q_u = 311.69 kPa

2 Safe Bearing Capacity (Qsafe) :

Factor of Safety (F.S.) : 2.50

Qsafe : 124.68 kPa

Limited to an allowable bearing pressure per running meter width: 110.00 kPa

2 Settlements

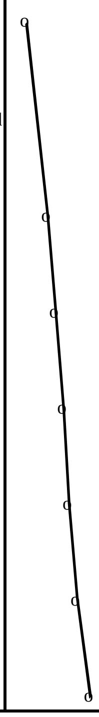
Since, the bearing strata are coarse-grained type, the settlements under the allowable safe bearing pressure of 110kPa will be of immediate elastic nature. The elastic settlements corresponding to a safe bearing pressure of 110kPa and SPT of 08 are computed to be in the order of 48mm which is within the permissible limits of 50mm for individual column footings and 70mm for rafts as per I.S:1904.

Project : Proposed Dedicated Freight Corridor at Khurja-Talheri at F1 on Eastern Freight Corridor in line with Tender No. HQ/EN/Pre. (Works)/MTC.

Location: At CH-(-)2356

Started On : 22/02/2009; Ended On : 22/02/2009 G.W.T: 8.20m

Depth of Top of Layer(m)	G.W.T. (m)	Soil Profile	Engineering Description of Soil	SPT - Details					raphical Representation of SP	Relative Density/Consistency	Type of Sample
								##	10 2(3(4(5(6(7(8(90		
				Depth of SPT (m)	0-15 cm	15-30 cm	30-45 cm	N-Value			
			Brownish Loose Silty Clayey Fine Sand	1.50	3	3	5	8		Loose	SS
				3.00	UDS Sampler Installed					Loose	UDS
3.50											
			Brownish Medium Dense Silty Fine Sand	4.50	7	7	9	16		M.Dense	SS
				6.00	7	9	10	19		M.Dense	SS
				7.50	8	10	12	22		M.Dense	SS
G.W.T				9.00	10	10	14	24		M.Dense	SS
				10.50	8	12	15	27		M.Dense	SS
12.00				12.00	11	14	17	31		Dense	SS



Bore Hole Terminated at a depth of 12.00m below the existing ground level

Fig. 2.1 Soil Profile at CH-(-)2356 Location